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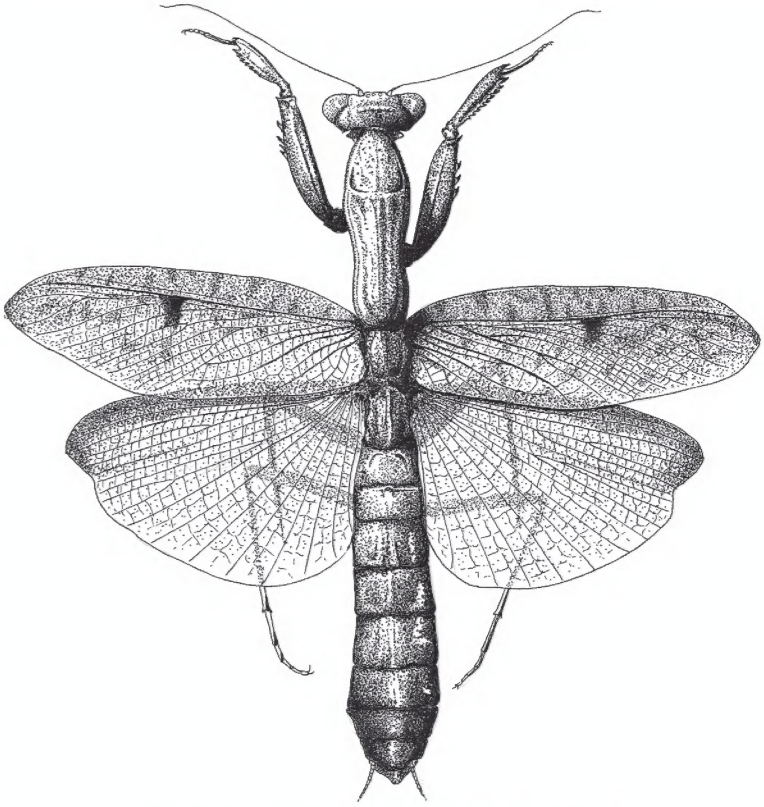

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ACRAEA TERPSICORE (LINNAEUS, 1758) (LEPIDOPTERA: NYMPHALIDAE) DISPERSES INTO CENTRAL-WESTERN QUEENSLAND

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Abstract

New distribution records of the Tawny Coster, *Acraea terpsicore* (Linnaeus, 1758) (Lepidoptera: Nymphalidae) from central-western Queensland are recorded here, suggesting that the species is expanding its range beyond that previously predicted. In addition, an unusual reddish-orange female colour form, with similar colouring to the males, is reported here from several locations in Queensland.

Key words: Distribution, colour forms, bioclimatic modelling

Introduction

The Tawny Coster, *Acraea terpsicore* (Linnaeus, 1758), originally from lowland India and Sri Lanka, has been extending its distribution across South-East Asia since 1988, including the Indonesian Archipelago (Braby *et al.* 2014). It was first recorded in Australia near Darwin in 2012 (Braby *et al.* 2014) and has since extended its range west to the Kimberley District of Western Australia (Kendall 2013), and east into Queensland (Wilson 2016). It reached the eastern coast of Queensland, at Cairns, in March 2017 (Miller 2017), where I also collected specimens the same year. Since then it has continued to spread along the Queensland coast, north into Cape York Peninsula and south past Mackay (Atlas of Living Australia 2020). It was recorded on Horn Island in southern Torres Strait in February 2016 (D. Lane & M. Moulds pers. comm.), April 2018 (R. Weir pers. comm.) and in February 2020 (M. Hopkinson pers. comm.).

During September and October 2019, a survey of butterflies was conducted in four national parks in central-western Queensland under Scientific Permit WITK18701717. The survey also included the town of Blackall. Adults of *A. terpiscore* were observed during this survey in all five locations. Whilst the region had suffered several years of severe drought prior to 2019, heavy rains in northern Queensland in early 2019 resulted in major flooding of several of the major rivers in the region. Idalia National Park, further to the east, and not located on a major river, missed much of this rain, as did the nearby town of Blackall.

Observations

Most adult *A. terpsicore* observed at the five locations (Fig. 1 and Table 1) were feeding at *Melaleuca* blossom or imbibing moisture along the creek and river channels, while at Bladensberg National Park the butterflies were collected along a shallow watercourse on a rocky plateau. Away from the moist watercourses, the majority of Welford and Diamantina National Parks consist of harsher environments of extensive sand dune and Mitchell grass plains where the butterflies were not observed. The only sighting in Idalia National Park was in mulga woodland, where the butterflies were imbibing moisture from the edge of

Table 1. Notes on locations of observation and collection of *A. terpsicore* in central-western Queensland.

*Abundance descriptors follow that of Braby (2016), with 'uncommon' referring to numbers observed of 3–10, and 'common' referring to numbers observed from 11–50.

National Park/Town	Specific Location	GPS coordinates	Notes including abundance descriptors
Bladensberg NP	Scrammy Rock Hole (Fig. 2)	22.5694°S 143.136°E	Common* (Voucher collected – Fig. 8)
Diamantina NP	Hunters Gorge (Diamantina River) (Fig. 3)	23.683°S 141.104°E	Uncommon
Welford NP	Little Boomerang Waterhole (Barcoo River)	25.179°S 143.142°E	Common (Voucher collected – Fig. 9)
Idalia NP	Monks Tank	24.793°S 144.704°E	1 sighted
Blackall	Barcoo River	24.426°S 145.461°E	1 sighted

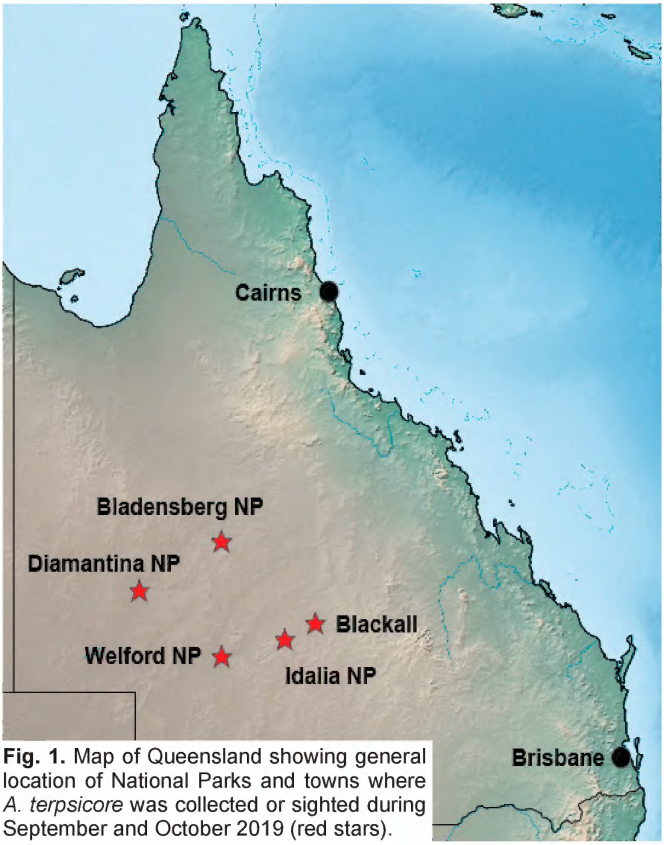
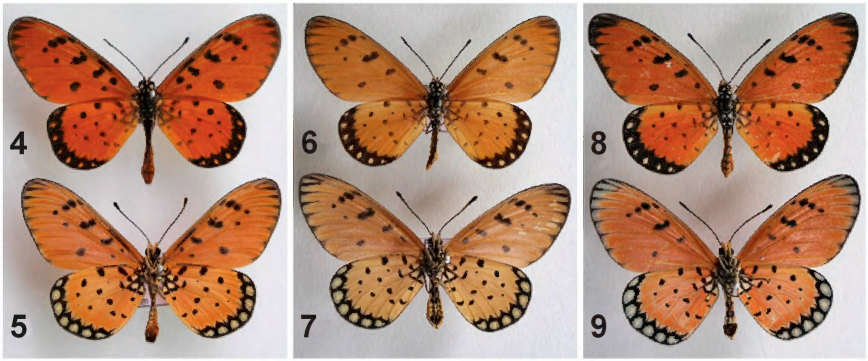


Fig. 1. Map of Queensland showing general location of National Parks and towns where *A. terpsicore* was collected or sighted during September and October 2019 (red stars).

Fig. 2. Creek near Scrammy Rock Hole, Bladensberg National Park.

Fig. 3. Hunters Gorge, Diamantina River, Diamantina National Park.



Figs 4–9. *Acraea terpsicore* (4, 5) males, upper and undersides: (4) Thorak Road, Darwin, N.T. (7.i.2013, RPW); (5) Channel Island, Darwin, N.T. (19.iv.2014, RDH); (6, 7) females (normal colour form), upper and undersides: (6) Channel Island, Darwin, N.T. (19.iv.2014, RDH); (7) Bentley Park, Cairns, Qld (EP 23.iv.2017, RM); (8–9) females (orange colour form), upper and undersides: (8) Scrammy Rock Hole, Bladensberg National Park, Qld (22. ix.2019, RDH); (9) Little Boomerang Waterhole, Barcoo River, Welford National Park, Qld (28.ix.2019, RDH).

an artificial dam. At Blackall, the only specimen sighted was flying in the vicinity of water near the Barcoo River.

Abbreviations and Material Examined

The following abbreviations refer to collectors' names: RDH – R.D. Ham; RM – Robert Miller; RPW – R.P. Weir. All specimens are in the collection of R.D. Ham, Cairns.

Discussion

These locations are several hundred kilometres further south and west of the most recent Queensland records from Belyando River Crossing and south-east of Hughenden (Atlas of Living Australia, accessed May 2020). In addition, these locations are outside the species' potential Australian geographical distribution as predicted by using ecological and bioclimatic niche modelling (Braby *et al.* 2014a), and the sites are in an arid to semi-arid region. Thus, it is possible that the presence of *A. terpsicore* recorded here was a result of dispersal aided by the high rainfall event in north-west Queensland in February 2019, and subsequent flooding of rivers into the Channel Country, promoting food plant growth, and thus the potential for dispersal. The Diamantina River, which passes close to Bladensberg National Park, and runs through Diamantina National Park, experienced major flooding, as did the Thompson River. Welford National Park is on the Barcoo River but is close to its junction with the Thompson River.

It is noteworthy that all of these locations are outside the known range of the primary host plant of *A. terpsicore*, *Hybanthus enneaspermus* (L.) F. Muell. (Violaceae), although *H. aurantiacus* (Benth.) F. Muell. occurs throughout the area, with suitable habitats for the plant in the areas where the butterflies

Fig. 10. Abdomen on female in Fig. 9 showing sphragis. Specimen collected at Welford National Park (28.ix.2019, RDH).

were observed (Simonsen *et al*. 2005). Pfitzner and Fargher (1976) recorded *A. andromacha* larvae feeding on a species of *Hybanthus* at Palm Valley in central Australia, mistakenly recording it as *H. enneaspermus* (Braby 2000), therefore it is possible that this could be the main host plant for *A. terpsicore* in drier locations. It may also be that *A. terpsicore* is utilising other host plants such as *Passiflora foetidus* L. which is utilised in Cairns (R. Miller pers. comm.) and the Atherton Tableland (D. Lane pers. comm.). At all locations except Idalia National Park, *A. andromacha* was also recorded during the survey, and therefore it is possible that the two species are utilising the same host plants, which is of interest regarding potential competition between the two *Acraea* spp, a point suggested by Braby *et al*. (2014b).

The near pristine condition of some of the *A. terpsicore* specimens, following the cold winter period, indicate that there were likely breeding populations present at that time. Being a species known to actively disperse over wide areas would allow it to readily exploit the ideal conditions following the flood event. Whether the populations can persist through extended drought periods, especially within a region in which the climatic conditions are not potentially ideal (Braby *et al.* 2014), remains to be seen.

Comparison of specimens collected and observed during the survey from these locations with specimens from Darwin and Cairns indicated that the females (Figs 8, 9) were very similar in colouration to the males (Figs 4, 5). These females are much brighter orange on both surfaces, compared to the more typical paler orange-brown colouring (Figs 6, 7). All had sphragal plugs (Fig. 10) so their sex was confirmed. C. Meyer (pers. comm.) has three similarly coloured females in his collection, from Kuranda, Weipa, and Darwin. Based on available collection data, it seems that females with this bright orange colouration are rarely observed within populations. Why all the female specimens observed during the time of the survey were of the orange form is unknown, but it may be related to the relatively dry climate of central-western Queensland.

Acknowledgements

Queensland Parks and Wildlife Service are thanked for the Scientific Permits under which the work was conducted. Special thanks to Carly Smith at Idalia National Park for her support. Thanks also to David Lane for help in preparation of the manuscript, Max Moulds for confirmation of the sex of specimens by examination, and Richard Weir, Cliff Meyer and Mark Hopkinson for their input on the colouration of females, and providing locations where they have encountered this species.

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BRABY, M.F., BERTELSMEIER, C., SANDERSON, C. and THISTLETON, B.M. 2014a. Spatial distribution and range extension of the Tawny Coster butterfly, *Acraea terpsicore* (Linnaeus, 1758) (Lepidoptera: Nymphalidae), in South-East Asia and Australia. *Insect Conservation and Diversity* **7:** 132–143.

BRABY, M.F., THISTLETON, B.M. and NEAL, M.J. 2014b. Host plants, biology and distribution of *Acraea terpsicore* (Linnaeus, 1758) (Lepidoptera: Nymphalidae): a new butterfly for northern Australia with potential invasive status. *Austral Entomology* **53:** 288–297.

BRABY, M.F. 2016. *The complete field guide to butterflies of Australia.* 2nd edition. CSIRO Publishing, Clayton South; 382 pp.

KENDALL, R. 2013. A new immigrant butterfly for Australia: *Acraea terpsicore* (Linnaeus 1758). *Metamorphosis Australia* **70:** 4–6.

MILLER, R. 2017. They have finally arrived! *Metamorphosis Australia* **85:** 37–39.

PFITZNER, J. and FARGHER, R.K. 1976. Butterflies of central Australia. *Australian Entomological Magazine* **2:** 117–122.

SIMONSEN, S.M., SANDO, L., IRELAND, D.C., COLGRAVE, M.L., BHARATHI, R., GÖRANSSON, U. and CRAIK, D.J. 2005. A continent of plant defense peptide diversity: cyclotides in Australian *Hybanthus* (Violaceae). *Plant Cell* **17:** 3176–3189.

WILSON, P. 2016. Tawny Coster arrives in Queensland. *Entomological Society of Queensland News Bulletin* **46:** 121–122.

BOOKS ABOUT AUSTRALIAN MOTHS 1805–2020: AN ANNOTATED BIBLIOGRAPHY

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Abstract

The 57 books and booklets that have dealt exclusively or substantially with the Australian moth fauna are referenced and described together with notes on contents, key reviews and current access. Commentary on any overarching series of publications within which these volumes may have been organised is also presented. Of particular current relevance are the on-going *Monographs on Australian Lepidoptera* series (CSIRO Publishing) and the *Moths of Victoria* sequence (Entomological Society of Victoria). Considerable attention is also given to the moth-related publications of the Scott family in Sydney in the nineteenth century and subsequent commentaries on that oeuvre. An unannotated list of relevant global catalogues and name lists is also included. Finally, major gaps in the literature and the dynamic interaction between books and electronic media are discussed.

Key words: moths, Lepidoptera, books, Australia, bibliography

Introduction

The very first moths from Australia to be noted by the western scientific world were those described by Johan Christian Fabricius' work of 1775 from the collections made by Joseph Banks and his colleagues during the visit of the *Endeavour* to our shores in 1770. Fabricius (1775) includes descriptions of eight species of Australian moths (and many more butterflies) the earliest of which (by page priority) was *Bombyx* (now *Donuca*) *castalia* (Erebidae). The description of this species appears on page 559 of Fabricius' 832-page tome beating *Bombyx* (now *Pararguda*) *australasiae* (Lasiocampidae) by three pages. Fabricius' book, of course, described many species of moths and other insects from around the world.

The first works that restricted themselves to descriptions of the Australian fauna and included substantial accounts of Australia moths were those of Donovan and Lewin, both of which appeared in 1805. Donovan's published names, however, have been given priority over those of Lewin. Accordingly, the notodontid *Epicoma tristis* is attributed to Donovan and takes priority over *Bombyx tristis* Lewin. In a similar fashion the name of the tineid *Moerarchis australasiella* (Donovan) precedes the junior synonym, *Tinea cossuna* (Lewin). This is generally supposed to reflect the fact that the plates in Donovan are individually dated (at January 1805) whereas (it is supposed) the Lewin plates were not. This is indeed the case for the plate of *Bombyx (=Epicoma) tristis* which is undated in the Lewin work. Lewin's plate of *Tinea (=Moerarchis) cossuna* is, however, faintly marked as 1802, but whether this represents the date of field observation or plate production is not clear. Neville (2012) states "[Lewin] completed most of the plates by June 1803, only one, *Cizara ardeniae,* is dated 1804. On the 4 March 1804 the *Sydney Gazette* announced that Mr Lewin was sending to England in the

Calcutta parts of his work". He sent 50 copies of each of his 18 engraved plates on the *Calcutta*. None of this tells us anything about the dates of publication which is the critical point for nomenclatural priority but it does tell us that the reason given for allocating priority to Donovan is unfounded.

We explore this issue further in the individual entry for Donovan (below).

Such decisions are of importance to nomenclaturists of course. From the point of view of bibliographers, however, it is the first edition of Lewin's (1805) work that can claim to be the first book-length work entirely devoted to Australian moths.

Lewin's book is of great historical and bibliographic interest (Wantrup, 2011) with the superb etched plates produced in the infant colony of New South Wales just fifteen years after the colony's establishment (see below).

Books on, or highly relevant to, the Australian moth fauna have appeared irregularly ever since. In this annotated bibliography we have set ourselves a set of rules as to what to include and exclude.

We include only works that have appeared as separately published books or booklets. A bibliography that encompassed all publications on the Australian moth fauna would be huge indeed (see, for example, Daniels, 2004). Sometimes the books involved also include information on other Lepidoptera, even other Orders, but in these cases substantial and useful parts of the work present information on the moths. In a few cases the material of relevance and use to Australian workers is embedded in works that deal with particular families and are global in scope. We include a selection of these. Finally, we include, generally without further comment, a list of past and current global check- and name-lists pertinent to the Australian fauna.

It is a perhaps curious fact that the three most prolific describers of Australian moths, Edward Meyrick, A. Jefferis Turner and Oswald B. Lower, hardly figure in the core of this bibliography. They wrote many papers, but not books, on Australian moths. We note however that modern compendia of their papers may be available (see, for example, Meyrick, *op. cit.*). As scanned computer-generated facsimiles become cheaper it will be increasingly hard to keep up with these compendia and print-on-demand publications of old works or, indeed, even collections of articles from platforms such as Wikipedia. We have listed only one of many here, that of Meyrick, by way of example. These publications are of varying quality (often terrible) and invariably add nothing new. They lack bibliographic information but may have an ISBN.

For most of the works we give bibliographic details and a short description of the history, scope and contents of the work. For modern works we include references to some of the published reviews that have appeared that deal with particular works. These references to book reviews are not complete: reviews may appear in very obscure places and are not always fully indexed. Finally, we indicate the current availability (as of January 2020) and means of access to the works. For many of the earlier 'classical' works, long out of copyright, electronic scans exist

Figs 1–4. Some key works on Australian moths: (1) *Moths of Australia* by I.F.B. Common, Second Issue (1993); (2) *Our Insects* by E.J. Dumigan (1934); (3) *Caterpillars, Moths and their Plants* by McQuillan *et al*. (2019); (4) *Transformations* by V. Finney (2018).

and are readily accessed on the Internet. Major reference libraries in each state also hold most of these in their original forms.

THE BIBLIOGRAPHY

In this bibliography we list works alphabetically. We have added separate entries for the three on-going series of moth books (*Monographs on Australian Lepidoptera, Moths of Victoria* and *Lepidoptera of Victorian National Parks*). We also focus on the body of work ascribed to Alexander Walker, Harriet and Helena Scott.

In our usage the designation *op. cit.* means that the cross-referenced work also has an account within the bibliography.

BRABY, M. and OLSEN, P. 2011. *A Flutter of Butterflies.* National Library of Australia, Canberra; vi + 106 pp.

This beautiful work is an account of the intersection of art and science as represented by illustrations of the Lepidoptera. In spite of the title many of the illustrations are of moths, often co-habiting plates containing a range of both butterflies and moths. The work contains a reproduction of the watercolour sketch by George Raper, midshipman on the first fleet's flagship, *Sirius,* of *Nyctemera amica*: the first illustration (*c.* 1788) of any Australian lepidopteran. The book is organised into accounts of the work of nine noted artists from Edward Donovan (1768–1837) to Frantisek Gregor (b. 1926). The moth illustrations by some of these artists are largely covered in other works in this bibliography (Donovan 1805; Finney 2018; Lewin 1805; Scott 1864, 1890–98; Ord 1988; Tarmann, 2004; *op. cit.*). Additional artists noted are Willian Elford Leach and Richard Polydore Nodder (1 arctiine illustrated), Louisa Anne Meredith (six species of various families incorporated into book-covers and botanical works), Marrianne Collinson Campbell (1 day-flying moth) and Marian Ellis Rowan (1 day-flying moth as part of a botanical illustration).

Reviews:
Ambrose, G. 2012. *Victorian Naturalist* **129**: 187.
Atkins, A. 2011. *Metamorphosis Australia* **#63**: 35–37.
Edwards, E.D. 2011. *Richmond Birdwing Conservation Network Newsletter* #**22**: 39–40.
Access: in print, available from the publishers and bookshops.

BRABY, M.F., FRANKLIN, D.C., BISA, D.E., WILLIAMS, M.R., WILLIAMS, A.A.E., BISHOP, C.L. and COPPEN, R.A.M. 2018. *Atlas of Butterflies and Diurnal Moths in the Monsoon Tropics of Northern Australia.* ANU Press, Canberra; xxxii + 430 pp.

This spectacular book presents life-histories, phenology and distribution data with an analysis of the conservation status of 230 species of Lepidoptera of the monsoon ('wet-dry') tropics of the Northern Territory. Fifty-two species of day-flying moths are covered in this fashion.

Reviews:
Edwards, E.D. 2019. *Austral Entomology* **58**: 919–920.
New, T.R. 2019. *Journal of Insect Conservation* **23**: 433–434.
Orr, A.G. 2019. *Australian Entomologist* **46**: 157.
Access: in print and available for free download from https://press.anu.edu.au/publications

CLYNE, D. 2009. *The Secret Life of Caterpillars*. New Holland Publishers, Sydney; 48 pp.

Although published under the Young Reed imprint of New Holland Publishers all ages can appreciate this book. It contains excellent images of many moths, as well as butterflies, and their life histories. Most notable of these is a sequence of photographs showing the steps a larva of *Metura* sp. (Psychidae) traverses in adding a stick to its silken case.

Access: available from second-hand booksellers.

COMMON, I.F.B. 1963. *Australian Moths,* Jacaranda, Brisbane; 129 pp.

This was the first book wholly on Australian moths published for over 60 years (but note Dumigan, 1934, *op. cit.* below) and the first of the seminal moth books produced by Ian Common (1917–2006). The book was reissued with additions and corrections in 1966. A small format book, this work describes and illustrates 331 species mostly as black and white photographs. It drew upon Common's immense knowledge and the authoritative identifications of the Australian National Insect Collection (ANIC) and remains a useful resource. The card covers and small size of the book did not lead to longevity.

Access: out-of-print but occasionally available from on-line booksellers. Most stock of the Jacaranda Pocket Guides was lost in the Brisbane floods of 1974. A few titles from among the almost 30 published guides by Jacaranda were reprinted by Axiom Books, but not, alas, *Australian Moths.*

COMMON, I.F.B. 1990. *Moths of Australia.* Melbourne University Press, Melbourne; vi + 535 pp.

This book, of all those listed in this bibliography, represented a 'coming-of-age' in studies of Australian moths. It was reprinted with a different jacket in 1993 (Fig. 1). It is essentially an account of moths globally, illustrated by the extensive Australian fauna. The work expanded upon the seminal Chapter on the Lepidoptera published by Common as part of the volume *Insects of Australia* (Common, 1970) and, together with that earlier work, stabilised many aspects of lepidopteran classification. *Moths of Australia* is authoritative, comprehensive and copiously illustrated. Although not a manual for identification it, nevertheless, contains *habitus* photos of over 1000 species covering all families, and including many of the commoner and more familiar taxa. The book (and author) was awarded the Whitley Medal by the Royal Zoological Society of New South Wales in 1991.

Reviews:
Dugdale, J.S. 1992. *New Zealand Entomologist* **15**: 87–88.
Kitching, R.L. 1991. *Australian Journal of Ecology* **16**: 421–422.
Mattoni, R.H.T. 1991. *Journal of Research in the Lepidoptera* **30**: 301.
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Rothschild, M. 1991. *Times Literary Supplement* **4598**: 20.
Scoble, M.J. 1991. *New Scientist* **1774**: 46–47.
Scoble, M.J. 1991. *Journal of Natural History* **25**: 815–816.
Wagner, D.L. 1991. *Quarterly Review of Biology* **66**: 499.
Access: out-of-print. Available as a Kindle e-book from Amazon.

COMMON, I.F.B. (1994–2000). *Oecophorine Genera of Australia.* 3 volumes, CSIRO Publishing, Collingwood, Victoria.

The three volumes on the genera of the Australian Oecophorinae were issued as part of the *Monographs in Australian Lepidoptera* (*op. cit.* below) and continued the 'top-down' approach to segments of the Australian moth fauna advocated by Robinson and Nielsen in Volume 2 of that Series. The Oecophorinae have radiated profusely in Australia and, as Common explains, represent about 20% of the entire list of described Australian Lepidoptera. The three volumes provide a generic framework for about 3400 species (*ca* 50% undescribed) and are a matchless overview of this largely endemic fauna, setting the taxonomic framework for future work regardless of how much of the fauna is described, known or yet-to-be-discovered.

The third and final volume appeared in 2000. All three volumes were completed after Common's formal retirement from the CSIRO Division of Entomology.

The three volumes are:

COMMON, I.F.B. 1994. *Oecophorine Genera of Australia I. The* Wingia *Group (Lepidoptera: Oecophorinae). Monographs on Australian Lepidoptera. Volume 3*. CSIRO Publishing, Melbourne; xvi + 390 pp.

Reviews:
Dunn, K.L. 1995. *Journal of the Australian Entomological Society* **34**: 16.
Hodges, R.W. 1995. *Quarterly Review of Biology* **70**: 225–226.
Access: out-of-print, available as an e-Book from CSIRO Publishing, commonly available through used booksellers.

COMMON, I.F.B. 1997. *Oecophorine Genera of Australia II. The* Chezala, Philobota *and* Eulechria *Groups (Lepidoptera: Oecophorinae). Monographs on Australian Lepidoptera. Volume 5*. CSIRO Publishing, Melbourne; xvi + 407 pp.

Access: out-of-print, available as an e-Book from CSIRO Publishing, commonly available through used booksellers.

COMMON, I.F.B. 2000. *Oecophorine Genera of Australia III. The* Barea *Group and unplaced Genera (Lepidoptera: Oecophorinae). Monographs on*

Australian Lepidoptera. Volume 8. CSIRO Publishing, Melbourne; xvi + 453 pp.
Review:
Mackey, P. 1995. *Australian Entomologist* **22**: 16.
Access: out-of-print, available as an e-Book from CSIRO Publishing, commonly available through used booksellers.

COUPAR, P. and COUPAR, M. 1992. *Flying Colours, Common Caterpillars, Butterflies and Moths of South-Eastern Australia.* University of NSW Press, Sydney; 119 pp.

A short, popular book introducing the Australian Lepidoptera, illustrated by the authors' excellent photographs of live adults and larvae. Seventy-one of the 94 species featured are moths, spanning most of the more familiar families.

Access: out-of-print, copies regularly available through on-line used book sites.

D'ABRERA, B. 1975 (dated 1974). *Moths of Australia.* Lansdowne Press, Melbourne; 86 pp.

This was d'Abrera's second book, following his large format *Butterflies of the Australian Region* (1971) but published in a much smaller format. Like that book, it is built around d'Abrera's photographs of mounted specimens, principally from the collections of the Natural History Museum, London. It also includes some images of living caterpillars and adults in the introductory sections. Following the general, and uncontroversial, section on biology, classification and nomenclature, the book presents examples and a short text on major families. It also includes a detailed account of 'how to make a moth collection'. Unlike the butterfly book, it is printed on matt paper that diminishes the quality of the illustrations. As a general introduction to the Australian moth fauna, its stated purpose, the book is clearly superseded by the works of later authors.

Reviews:
Common, I.F.B. 1975. *Australian Entomologist* **2**: 87–88.
Klots, A.B. 1976. *Journal of the New York Entomological Society* **84**: 253.
Access: out-of-print but readily available through on-line used book sites.

D'ABRERA, B. 1987. *Sphingidae Mundi. Hawk Moths of the World based on a Checklist by Alan Hayes and the Collection he curated in the British Museum (Natural History).* Classey, Faringdon, Oxfordshire; x + 226 pp.

Following the pattern of d'Abrera's many volumes within his *Butterflies of the World* series (why not *Rhopalocera Mundi* one wonders?), this volume presents excellent photographs of adult hawkmoths, principally from the collection of the Natural History Museum in London. It was, apparently, conceived as a joint project with Alan Hayes, curator of that collection. Hayes died before the volume was completed and, presumably, before he had the opportunity to check the final text. It contains a number of significant errors, yet, as Ian Kitching and Jean-Marie Cadiou (2000) point out, it remains 'the only readily available colour guide

to adult hawkmoths on a global basis'. Those authors also set out, successfully, to correct its taxonomic errors in their annotated checklist (*op. cit.* below). For Australian workers the work is now comprehensively superseded by the Moulds *et al.* (2020) volume (see below) but will remain of some importance for global comparisons as long as it is used in conjunction with the Kitching and Cadiou (2000) volume.

Reviews:
Dugdale, J.S. 1988. *New Zealand Entomologist* **11**: 84.
Moulds, M.S. 1988. *General and Applied Entomology* **20**: 56.
Oberprieler, R.G. 1988. *Journal of the Entomological Society of South Africa* **51**: 151–152.
Access: out-of-print but occasionally available for sale on-line.

D'ABRERA, B. 1998. *Saturniidae Mundi. Saturniid Moths of the World 3.* Goecke and Evers, Keltern; 171 pp.

Like d'Abrera's books on butterflies, this is a large format photographic catalogue principally of species in the collection of the Natural History Museum, London. It covers genera with Australian representatives such as *Opodiphthera, Samia, Attacus* and *Coscinocera.* Parts 1 and 2 of the series cover genera from other biogeographic regions. Widely, if mostly informally, criticised for its many inaccuracies as well as d'Abrera's creationist 'rants', the work has, nevertheless, been praised "at least for the type specimens figured" (Racheli, 2004).

Review:
Piegler, R.S. 1999. *Journal of the Lepidopterists' Society* **53**: 230.
Access: out-of-print but occasionally available for sale on-line.

DODD, A.P. 1940. *The Biological Campaign against Prickly Pear.* Commonwealth Prickly Pear Board, Brisbane; ii + 177 pp.

At first blush this might not immediately be conceived of as a 'moth book' yet it is an account of a biological and scientific drama within which a species of moth is the star. The phycitine pyralid, *Cactoblastis cactorum,* was introduced along with several other species of insect into Queensland from Argentina in 1925–27 in an attempt to control the prickly pear cactus (*Opuntia* spp.) (Fig. 9) which had alienated about 15 million hectares of grazing land following its introduction in the early days of colonization by Europeans (initially in the hope of establishing a cochineal dye industry to serve the needs of the red-coated army of the day). The introduced moth effectively controlled the cactus infestation within a few years. This work gives a blow-by-blow account of the entire process of development of what has become a classic example of biological control.

Access: long out-of-print but readily accessible through the National and State library system.

DODD, F.P. Undated (probably 1918). *Notes on the North Queensland and New Guinea Insect Collection of F.P. Dodd, with references to the climate and scenery of Kuranda and district.* Privately published, Cairns (2nd ed., Melbourne,

n.d.); 16 pp. (Facsimile reprint of 2nd edition, with foreword by G.B. Monteith, Queensland Museum, 1988; 2nd facsimile reprint, with revised foreword, Queensland Museum 1991).

The earliest of several booklets relating to the work and times of Frederick Parkhurst Dodd (1861–1937). Known familiarly as 'The butterfly man of Kuranda' (Monteith 1991, *op. cit.*) F.P. Dodd was the father of Alan Parkhurst Dodd (see above). In spite of his sobriquet, most of F.P. Dodd's writing and collecting activities were about moths (see, for example, Fig. 8). He supplied many tens of thousands of specimens of moths to museums and collectors all round the world (Lord Walsingham in the UK, alone, bought 18,000 moths from Dodd) and his specimens became type material for an enormous number of our tropical moths. He also worked extensively on life histories and published more than a dozen moth papers himself in the UK and France (Monteith 1991, Oberthür *et al.* 1916, *op. cit.*). This booklet was prepared to accompany the travelling exhibition of the Dodd collection that toured the eastern and southern states of Australia to considerable acclaim in 1918 and again in 1923.

Access: out-of-print; available from some libraries.

DONOVAN, E. 1805. *An Epitome of the Insects of New Holland, New Zealand, New Guinea, Otaheiti, and other Islands in the Indian, Southern and Pacific Oceans including the Figures and Descriptions of One Hundred and Fifty-three Species of the more Splendid, Beautiful, and Interesting Insects, hitherto discovered in those Countries, and which, for the most part have not appeared in the Works of any preceding Author.* Privately Published, London; iv + *ca* 134 pp., text unpaginated plus 41 unnumbered plates.

This work is often assumed to be the earliest illustrated book containing material on the Australian moths based on the dates printed on the plates. It appeared, however, in the same year as that of Lewin (1805) whose plates were prepared (but not necessarily dated, see above) earlier than those of Donovan. Donovan's work, unlike that of Lewin, contains illustrations and brief descriptions of insects from several orders. Nine of the 41 plates are devoted to moths representing the first descriptions and illustrations of 21 species ranging from sphingids to tineids, plus seven species previously described by Fabricius (1775). As discussed in the Introduction, Donovan's names have been given priority over those of Lewin on the, somewhat dubious, grounds of the dates appended to the plates. This priority was first proposed by Watson *et al.* (1980) and upheld by Nielsen *et al.* (1996) largely because, without knowing exact publication dates of the *books* (as opposed to the dates appended to the plates) no better solution presented itself.

Access: Original copies are held by the National and some State libraries, libraries of Deakin, Melbourne and Sydney universities, the Australian Museum, the Royal Geographical Society of South Australia and the CSIRO Black Mountain Library.

A digitised copy is available at: https://nla.gov.au/nla.obj-685690302

DUCKWORTH, W.D. and EICHLIN, T.D. 1974. *Clearwing Moths of Australia and New Zealand (Lepidoptera: Sesiidae).* Smithsonian Contributions in Zoology #180. Smithsonian Institution Press, Washington, DC; iii + 45 pp.

Only dubiously regarded as a 'book' we have nevertheless included this item in the bibliography because it is a stand-alone, independently paginated, publication that deals exclusively with an entire family of Australasian moths. It has been superseded by Kallies (2001). The Australian fauna consists of a mere 18 species, including the introduced pest species, *Synanthedon tipuliformis.*

Access: freely available on line at: https://repository.si.edu/handle/10088/5286

[DUMIGAN, E.J.] 1934. *Our Insects.* Compiled by the Syllabus Notes Committee of the South Coast Inspectoral District, Queensland Department of Education, Brisbane. Pole and Company, Brisbane; 212 pp.

A remarkable and little-known work (Fig. 2) produced by the mainly Toowoomba-based schoolteacher, E.J. Dumigan, and published anonymously as a support document for the teaching of 'Nature Study' in Queensland primary schools. Following an introductory and practical section in which children are encouraged to 'make collections' and work out life-histories, the greater part of the work deals systematically with commoner insects. One hundred and fifty of the 192 pages devoted to these accounts deal with the Lepidoptera and 66 of these describe species of moths. One hundred and twelve species are covered, each illustrated with a black and white photograph with, in many instances, photographs of larvae and/or pupae.

Access: out-of-print and hard to obtain. Copies are held in the National Library, The Queensland Museum and State Libraries of Queensland, NSW and Victoria.

FINNEY, V. 2018. *Transformations: Harriet and Helena Scott, Colonial Sydney's Finest Natural History Painters.* NewSouth Publishing, Sydney; 219 pp.

This book is a richly illustrated biography (Fig. 4) of the Scott family with a focus on the artistic endeavours of the sisters, Harriet and Helena. The account of their lives and work is placed within the context of the scientific and social life of colonial Sydney in the late 1800's. As well as high quality reproductions of many previously unpublished sketches and paintings, the volume provides useful details of the history and production process of the two Scott volumes (see below). This volume is undoubtedly the best account of the whole Scott story. Remarkably it was produced by NewSouth Publishing (in conjunction with the Australian Museum) in a very small print run, became out-of-print within 18 months of publication, and is difficult to access. There are no current plans for reprinting this interesting and important volume.

Review:
Freeman, C. 2020. *Historical Reviews of Australian Science* **31:** 65–66.

Access: out-of-print and difficult to obtain; copies offered on-line have very high asking prices (from AUD250 to US$500+); available in a number of public libraries.

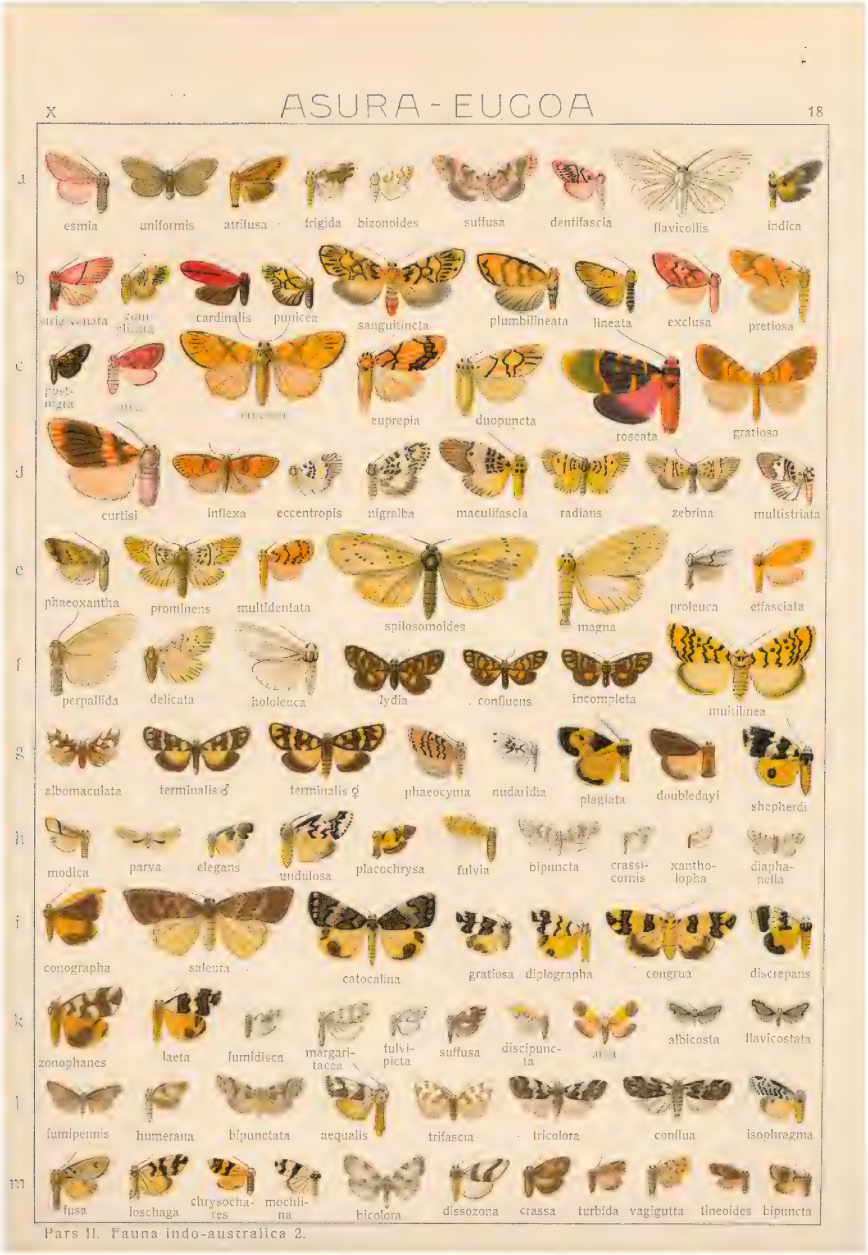


Fig. 5. Indo-Australian Arctiinae, Plate X from *The Macrolepidoptera of the Indo-Australian Fauna. Volume XI. Noctuiform Phalaenae* by A. Seitz (1924–26).

HORAK, M. (with contributions by F. KOMAI) 2006. *Olethreutine Moths of Australia (Lepidoptera: Tortricidae). Monographs on Australian Lepidoptera. Volume 10*. CSIRO Publishing, Melbourne; x + 522 pp.

This volume in the distinguished *Monographs* series (see below) was awarded the inaugural J.O. Westwood medal of the Royal Entomological Society of London in 2008. The book tackles a substantial part of the immense lineage of tortricids focussing on the subfamily Olethreutinae that, with about 450 species, represents about half of the Australian tortricid fauna. As in some other volumes in the series, Horak takes a genus-level approach to provide a framework for a fauna that, inevitably, holds many undescribed species. Ninety genera are reviewed and established to contain the 249 described and 200 unnamed species from Australia. Twelve of these genera are erected for the first time in this volume. Furumi Komai collaborated on the revision of the *Grapholita* group of eleven genera. The volume is well illustrated using black and white photographs of representative adults, genitalia and wing venation.

Reviews:
Brown, J.R. 2008. *Systematic Entomology* **33**: 210–212.
Brown, J.W. 2007. *Proceedings of the Entomological Society of Washington* **109**: 500–502.
Hoare, R. 2007. *New Zealand Entomologist* **30**: 91–92.
Nieukerken, E.J. van 2007. *Tidjschrift voor Entomologie* **150**: 262.
Nuss, M. 2007. *Nota Lepidopterologia* **30**: 204–205.
Access: out-of-print, available as an e-Book from CSIRO Publishing, commonly available through used booksellers.

KAILA, L. (with contributions by K. SUGISIMA) 2011. *Elachistine Moths of Australia (Lepidoptera: Gelechioidea: Elachistidae). Monographs on Australian Lepidoptera. Volume 11*. CSIRO Publishing, Melbourne; x + 443 pp.

This is an extraordinary book. It describes the 148 known Australian Elachistidae: Elachistinae. The subfamily contains a large diversity of minute gelechioid moths, the larvae of which are miners in grass and sedge blades and stems. Kaila describes 128 of the 148 as new species. These numbers compare with the 19 species included by Nielsen in the Nielsen, Edwards and Rangsi *Checklist* (1996 *op. cit.,* below), six of which Kaila excludes from the subfamily. All species, their pupae and mines (where available) are illustrated in colour together with habitat photos and black and white genitalia photos for males and females. Extensive detail is given on the morphology, ecology and distribution of each taxon. One of its reviewers says: "*This book is an outstanding example of the fundamental backbone that understanding and documenting biodiversity requires*".

Reviews:
Fiedler, K. 2011. *Journal of Research in the Lepidoptera* **44**: 49–50.
Landry, J.-F. 2011. *Nota Lepidopterologia* **34**: 111–114.
Access: out-of-print, available as an e-Book from CSIRO Publishing, commonly available through used book sellers.

LEWIN, J.W. 1805. *Prodromus Entomology. Natural History of Lepidopterous Insects of New South Wales. Collected Engraved and faithfully Painted after Nature.* Thomas Lewin, London; i–ii (1st edn), i–vii (2nd edn) + 20 pp.

This was the first book to deal exclusively with Australian moths and also the first book about Australia in which the plates were engraved in Australia. First privately published and printed in England in 1805, it depicts the life histories of 18 species delineated and coloured, each on a separate page. A second issue (dated 1822) followed after Lewin's death. That edition had an additional plate: a frontispiece showing the butterfly *Delias harpalyce* (interestingly this addendum illustrated the living adult butterfly only—in contrast to the moth plates, and was produced by a quite different engraving process). Editions Renard, in 2007, published a third edition based on the 1822 edition in three limited collectors' versions comprising in total 200 copies. These contained a facsimile of Lewin's book and various supporting documents, explanatory text and bindings. There was a "Standard Edition" (100 copies), a "Deluxe Edition" (70 copies) and a large paper "Special Edition" (30 copies). The 'special edition' reproduced plates from both Lewin's first and second edition. The supporting documents were "Historical, Biographical and Publication Notes", a list of the current names of the Lepidoptera depicted in Lewin's book, and a partial census of all the extant copies of Lewin's work on the Lepidoptera which Julian Renard could trace. Of bibliographic interest is the great variety in *actual* publication dates of the second issue which was often a collation of 'original' (1805) plates bound together with separately, and later printed text and interleaves. Neville (2012) discusses Lewin's publications further.

Access: a digitised copy of the first edition is available at: https://nla.gov.au/nla.obj-1229657. Copies of the Renard facsimiles are still available for purchase.

MATTHEWS, M. 1999. *Heliothine Moths of Australia. A Guide to Pest Bollworms and related Noctuid Groups. Monographs on Australian Lepidoptera. Volume 7.* CSIRO Publishing, Melbourne; x + 320 pp.

This was the first of the *Monograph* series to be illustrated in colour and, hence, the first that might be used as a 'compare the pictures' guide for identification. It is, however, much more than that. The Heliothinae are a subfamily of the Noctuidae that include species of immense economic importance (*Helicoverpa armigera* and *H. punctigera*, for example) and it was this importance that drove (and funded) the revision presented by Matthews. He describes all 37 known species of the subfamily from Australia (eight of them as new) plus one likely future invader. Both sexes of all species are illustrated as set specimens with a range of additional photos of living adults, larvae and pupae. Genitalia, wing venations and leg structures are illustrated in black and white.

Reviews:
Heppner, J.B. 1999. *Tropical Lepidoptera* **10**: 50.
Heppner, J.B. 2000. *Florida Entomologist* **83**: 206–207.

Access: out-of-print, available as an e-Book from CSIRO Publishing, commonly available through used book sellers.

McFARLAND, N. 1988. *Portraits of South Australian Geometrid Moths.* Sierra Vista, Arizona; iv + 400 pp. Privately published, 500 copies. Available on-line in 2020 at US$75.00.

This work illustrates seventy-two species of South Australian geometrid species reared and documented by the author. It is a very large format, paperback book replete with beautiful black and white photographs of moths and life-histories. Its slightly idiosyncratic layout is, nevertheless, easy to use.

Reviews:
Edwards, E.D. 1989. *Australian Entomological Magazine* **16**: 15–16.
Rindge, F.H. 1989. *Journal of the New York Entomological Society* **97**: 122–123.
Access: out-of-print but copies are available for purchase in on-line book sites.

McQUILLAN, P.B. and FORREST, J.A. 1985. *A Guide to Common Moths of the Adelaide Region.* Special Education Bulletin 5. South Australian Museum, Adelaide; v + 52 pp.

A slim volume describing and illustrating 114 South Australian species with details on their natural history. Mounted specimens of adults of each selected species are illustrated in seven black and white and eight colour plates. There is a useful list of known larval host-plants.

Review:
Moulds, M.S. 1986. *Australian Entomological Magazine* **12**: 126.
Access: out-of-print; widely available from libraries; may be available for purchase in whole or part as print-on-demand from the National Library of Australia.

McQUILLAN, P.B., FORREST, J.A., KEANE, D., and GRUND, R. 2019. *Caterpillars, Moths and their Plants of Southern Australia.* Butterfly Conservation South Australia, Adelaide; x + 196 pp.

This fine work (Fig. 3) was conceived as a follow up to McQuillan and Forrest (1985, *op. cit.*) and is an excellent example of how knowledge, approaches and technical publishing have progressed over the intervening 34 years. Following a short introduction on the ecology, study and conservation of moths, the work contains a fascinating history of previous workers on the South Australian moth fauna from Charles Wilson (1818–1884) onwards, accompanied by a full set of dour or rather furtive looking portraits. An introduction to the main moth families and sub-families follows. The central section of the book comprises accounts of the life-histories of over 110 species (or small groups of species) with excellent full-colour photographs of early stages and adults. Although focussed on the South Australian fauna this book, as its title implies, is of interest to all those interested in the fauna of the southern half of the continent (or, indeed, beyond).

Review:
Anonymous. 2019. *Metamorphosis Australia* **95**: 28–29.

Access: in print, available from the publishers on-line and c/- the South Australian Museum.

MEYRICK, E. Undated (*c.* 2010). *Descriptions of Australian Micro-lepidoptera.* [1878–1888]. Hardpress Classics Series, Hardpress Publishing, Miami, Florida; Unpaginated.

This is one of an increasing number of facsimile compilations of the research papers of better-known earlier workers or straightforward, sometimes very crude, facsimiles of rare books. These books are published cheaply: some may be print-on-demand. With cheap automated publishing many more books in this genre may be anticipated, sourced, principally, in India or the USA, and, indeed, probably already exist. These books often lack the usual bibliographic details but usually do have an easily and uncritically obtained ISBN. We have not followed up on this burgeoning and open-ended source of 'books' and list this Meyrick collection merely as an example of how they may appear.

Access: available on-line.

MONOGRAPHS ON AUSTRALIAN LEPIDOPTERA. 1989–2020, (on-going). CSIRO Publishing, Melbourne.

This on-going series publishes taxonomic revisions, checklists and accounts of the Australian Lepidoptera. Originally the brainchild of Ebbe Schmidt Nielsen, Marianne Horak took over as its editor-in-chief following Nielsen's untimely death in 2001. Thirteen volumes have been published to date culminating, in 2020, with Moulds *et al.*'s *Hawkmoths of Australia.* All but two of these 13 volumes deal with a family or subfamily of Australian moths. Volume 4 is a Checklist of the Australian Lepidoptera (Nielsen, Edwards and Rangsi, 1996) and Volume 6 is a compendium of articles on the biology of Australian butterflies (Kitching *et al.,* 1999).

Each of the 11 moth volumes and the checklist is dealt with independently in this bibliography.

MONTEITH, G.B. 1991. *The Butterfly Man of Kuranda—Frederick Parkhurst Dodd.* Queensland Museum, Brisbane; 32 pp. (reprinted and revised 2010, 46 pp.).

This fascinating and well-illustrated account is both a biography of F.P. Dodd (and his various descendants) and an account of his work on moths and butterflies. Dodd resigned from his job as a banker to become a full-time lepidopterist. He supplied thousands of specimens to museums and private collectors worldwide but also carried out insightful work on some of the most challenging life histories of Australian Lepidoptera. Although celebrated for his work with butterflies Dodd's collecting and research were principally on species of moths. These included the massive hercules moth, the wood-boring giant cossids and hepialids, predatory cyclotornids and ectoparasitic epipyropids. The work brings to a modern audience the fascinating life of a very non-traditional entomologist. The first edition was

A4 size and produced and designed as a work of art in itself (Fig. 8). The reprint is of A5 size with lesser production values, but more colour illustrations.

Access: out-of-print; available through libraries and the second-hand book trade.

MONTEITH, G.B. 2010. *The Dodd Collection of Butterfly and Insect Cases.* Queensland Museum, Brisbane; 30 pp.

This short work presents photographs of all the display cases in the Dodd display collection that were included in a special exhibition held by the Queensland Museum in 2010. In addition to the images the booklet describes briefly the contents of each case. Material from Australia and New Guinea is included (as in the original Dodd travelling exhibition—see Dodd (undated, *op. cit.*)). Coloured illustrations of all 27 cases are included. Ten of these are of Australian moths. The arrangements of specimens within the cases were set out by Dodd to charm and impact upon the eye rather than as traditional taxonomic resources. These include the case shown in Fig. 11 that spells out a Longfellow verse using beetles and set specimens of moths and butterflies.

Access: out-of-print and available only briefly. The Queensland Museum library holds copies.

MOTHS OF VICTORIA. 2008–2017, (on-going). Entomological Society of Victoria, Melbourne.

This is a series of short guidebooks to the moth fauna of Victoria, initiated by Peter Marriott. Marriott is the sole author of four of the eight volumes to date, is lead author in a further volume, and a participating co-author in the remainder. Each booklet deals with a family or part of a family of macro-moths. Each comprises 36 pages (34 in the case of Volume 1) within which species of the subject taxa are listed and illustrated. Each issue has an appended compact disc that contains a wide range of further images of mounted and living material, together with information on life-histories, plant associations and distributions. Careful technical management of the CD-based information will be required if it is to be long-lived. The series is on-going and is undoubtedly useful for students of Australian moths everywhere, but especially in Victoria and adjacent parts. A ninth volume extending coverage of the Noctuoidea will appear in 2020. The issues available to date are as follows.

MARRIOTT, P. 2008. *Moths of Victoria. Part 1. Silk Moths and Allies, Bombycoidea.* Entomological Society of Victoria, Melbourne; 36 pp. + CD.

Review:

Gibson, L. 2009. *Victorian Entomologist* **126**: 218.

A second edition was issued in 2012.

Access: in print, available from the Entomological Society of Victoria and booksellers.

MARRIOTT, P. 2009. *Moths of Victoria. Part 2. Tiger Moths and Allies, Noctuoidea (A).* Entomological Society of Victoria, Melbourne; 36 pp. + CD.

A second edition was issued in 2015.

Access: in print, available from the Entomological Society of Victoria and booksellers.

MARRIOTT, P. 2011. *Moths of Victoria. Part 3. Waves, Carpets and Allies, Geometroidea (C).* Entomological Society of Victoria, Melbourne; 36 pp. + CD.

Access: in print, available from the Entomological Society of Victoria and booksellers.

MARRIOT, P. 2012. *Moths of Victoria. Part 4. Emeralds and Allies, Geometroidea (B).* Entomological Society of Victoria, Melbourne; 36 pp. + CD.

Access: in print, available from the Entomological Society of Victoria and booksellers.

HEWISH, M., MARRIOTT, P., EDWARDS, E.D., KALLIES, A. and WILLIAMS, S. 2016. *Moths of Victoria. Part 5. Satin Moths and Allies, Geometroidea (A) Geometridae Ennominae-Nacophorini.* Entomological Society of Victoria, Melbourne; 36 pp. + CD.

Access: in print, available from the Entomological Society of Victoria and booksellers.

KALLIES, A., MARRIOTT, P. and HEWISH, M. 2015. *Moths of Victoria. Part 6. Ghost Moths. Hepialidae and Allies.* Entomological Society of Victoria, Melbourne; 36 pp. + CD.

Access: in print, available from the Entomological Society of Victoria and booksellers.

HEWISH, M., MARRIOTT, P., EDWARDS, E.D., KALLIES, A., WILLIAMS, S. and BYRNE, C. 2014. *Moths of Victoria. Part 7. Bark Moths and Allies, Geometroidea (D) Geometridae-Ennominae-Small Tribes, Uraniidae.* Entomological Society of Victoria, Melbourne; 36 pp. + CD.

Access: in print, available from the Entomological Society of Victoria and booksellers.

MARRIOTT, P., EDWARDS, E.D., KALLIES, A., HEWISH, M. and WILLIAMS, S. 2017. *Moths of Victoria. Part 8. Night Moths and Allies, Noctuoidea (B).* Entomological Society of Victoria, Melbourne; 36 pp. + CD.

Access: in print, available from the Entomological Society of Victoria and booksellers.

[MOTHS OF VICTORIAN NATIONAL PARKS]. 2017–2019, (on-going). Entomological Society of Victoria, Melbourne.

This is not a formal series, nevertheless the three booklets issued so far do form a sequence based on surveys of Lepidoptera in three Victorian National Parks. The issue of booklets is irregular in timing. Each number consists of a brief introduction and then numerous coloured photographs of moths at light sheets. Photos are small, up to 36 per page, but usually clear. There are some habitat photos. The moths are identified at the end of the booklet. These booklets

contain identified photographs in print form of moths, including micro-moths, not available elsewhere. The issues available are as follows.

MARRIOTT, P. 2017. *Lepidoptera of the Gippsland Lakes and nearby Hinterland*. Entomological Society of Victoria. Melbourne; 31 pp. Figures 600 species.

Access: in print, available from the Entomological Society of Victoria.

HARRIS, K. and MARRIOTT, P. 2018. *Morwell National Park: Lepidoptera and Neuroptera*. Entomological Society of Victoria. Melbourne; 44 pp. Figures 670 species.

Access: in print, available from the Entomological Society of Victoria.

MARRIOTT, P., HEWISH, M., HARRIS, K., POWERS, C., MULES, D., PIERCE, F. and HEWISH, D. 2019. *Great Otway National Park: Lepidoptera*. Entomological Society of Victoria. Melbourne; 44 pp. Figures 930 species.

Access: in print, available from the Entomological Society of Victoria.

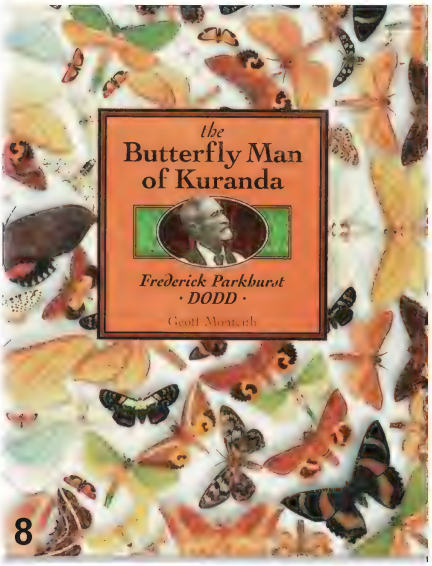
MOULDS, M.S., TUTTLE, J.P. and LANE, D.A. 2020. *Hawkmoths of Australia: Identification, Biology and Distribution. Monographs on Australia Lepidoptera Volume 13.* CSIRO Publishing, Melbourne; x + 414 pp.

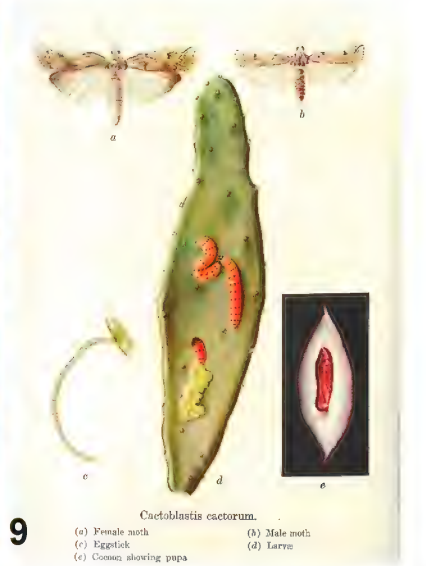
This is the latest volume in the *Monograph* series and is, undoubtedly, one of the finest books on hawkmoths (perhaps indeed on any moths) ever produced. It deals with the 87 species of sphingids occurring in Australia (and its outlying territories) revising the status of nine and the generic placement of a further species. The work acknowledges and follows the classification and nomenclature of Kitching and Cadiou (2000) (*loc. cit.*). There are 92 plates of which 80 are in colour. For an astounding 70 of the 87 species, eggs, larvae *in each of their instars,* and pupae are illustrated in colour together with, in most cases, photos of the living adult. *Habitus* photos of set specimens of all species occupy ten colour plates. The male genitalia of all species are illustrated in black and white. The text describes the synonymy, distribution, habitat and biology of every species together with a distribution map.

Reviews:
Brown, G. 2020. *General and Applied Entomology* **47:** 37–38.
Hendry, P. 2020. *Metamorphosis Australia* **96:** 34–37.
Kesting-Handly, T. 2020. *News of the Lepidopterists' Society* **62**, 2 pp.
Lachlan, R.B. 2020. *Australian Entomologist* **47:** 80–82.
Owen, G. 2020. *Circular, Society for Insect Studies* **#204:** 11–12.
Access: in print and as an e-Book, available from the publishers.

NIELSEN, E.S., EDWARDS, E.D. and RANGSI, T.V. (eds) 1996. *Checklist of the Lepidoptera of Australia. Monographs on Australian Lepidoptera Volume 4.* CSIRO Publishing, Melbourne; xiv + 529 pp.

This volume in the *Monographs* series will remain one of the most used volumes in any library of moth books. It represents a 1996 snapshot of the known moth fauna as represented by the incomparable Australian National Insect Collection,





Figs 6–9. Some illustrations from books on Australian moths: (6) Plate 7 from *Australian Lepidoptera and their Transformations* by A.W. Scott (1864) illustrating *Chelepteryx collesi* (Anthelidae); (7) Plate 1 from *Zygaenid Moths of Australia* by Tarmann (2004) illustrating males of *Pollanisus viridipulverulenta*, paintings by Frantisek Gregor; (8) Cover of *The Butterfly Man of Kuranda* by Geoff Monteith (1991), note the absence of butterflies in the image; (9) Illustration of *Cactoblastis cactorum* and its interaction with *Opuntia* from *The Biological Campaign against Prickly Pear* by Alan Dodd (1940).

many other repositories and the very extensive literature. The work lists all 10583 valid species names available at the time in the context of the 17280 total names that have been applied within the fauna. Many synonymies, combinations and changes of status at all taxonomic levels are included. Accordingly, it is the initial go-to volume for anyone working on Australian moths. That having been said, no checklist remains current and many changes and additions to the Australian fauna have been made since this list was published (see, for example, many of the later volumes in the self-same *Monograph* series). Other more fundamental changes must also be factored in by the serious student. Perhaps the most important of these has been the re-classification of the Noctuoidea resulting from the molecular phylogenies of Zahiri *et al.* (2011) and later derived works. These changes have been incorporated into the BOLD molecular databases as well as the *Australian Faunal Directory* both of which are readily accessible electronically. The published version of the Checklist contained a searchable compact disc as well as brief introductory accounts of each family.

Reviews:
Crosby, T.K. 1996. *New Zealand Entomologist* **19**: 95–96.
DeVries, P.J. 1998. *Annals of the Entomological Society of America* **91**: 358.
Heppner, J.B. 1996. *Tropical Lepidoptera* **7**: 154.
Sands, D. 1997. *Australian Journal of Entomology* **36**: 332–333.
Access: out-of-print, commonly available through used booksellers.

NIELSEN, E.S. and KRISTENSEN, N.S. 1989. *Primitive Ghost Moths. Morphology and Taxonomy of the Australian Genus* Fraus *Walker* (*Lepidoptera: Hepialidae.* s. lat.). *Monographs on Australian Lepidoptera Volume 1*. CSIRO Publishing, Melbourne; xii + 206 pp.

This was the first of the influential *Monographs on Australian Lepidoptera* (*loc. cit.*) and set the authoritative tone that has been maintained subsequently. It built on Nielsen and Robinsons' (1983) monograph on the Hepialidae of southern South America. *Primitive Ghost Moths* deals exclusively with the 'primitive' endemic genus *Fraus* covering 25 species, 17 of which were newly described in this volume. *Habitus* and genitalia preparations are illustrated in black and white (only). The taxonomic treatment is preceded by extensive and detailed sections describing the morphology, biology, diversity and distribution of the genus.

Reviews:
Mattoni, R.H.T. 1989. *Journal of Research of the Lepidoptera* **27**: 274.
Naumann, I.M. 1991. *Journal of Zoological Systematics and Evolutionary Research* **29**: 154–155.
Pellmyr, O. 1990. *Quarterly Review of Biology* **65**: 93.
Wagner, D.L. 1991. *Journal of the Lepidopterists' Society* **45**: 243.
Access: out-of-print, available as an e-Book from CSIRO Publishing, commonly available through on-line and used booksellers.

OBERTHÜR, C., HOULBERT, C. and DODD, F.P. 1916. *Contributions à l'étude des Grands Lépidoptéres d'Australie (Genres* Coscinocera *et* Xyleutes*),* Études

de Lépidoptèrologie Comparée, Fascicule XI bis. Imprimerie Oberthür, Rennes; 121 pp.

A volume produced by the French lepidopterist, Charles Oberthür, comprising a set of several separately authored sections on the giant saturniid and cossid moths of Australia, *viz.*:

OBERTHÜR, C. Introduction (4 pp.).

DODD, F.P. Noise-producing Lepidoptera (2 text pages in English, then translated into French).

OBERTHÜR, C. Notes bibliographiques et figuration de *Coscinocera hercules* (5 pp., + 7 figures).

DODD, F.P. Biological notes on *Coscinocera hercules* Misk. (2 pp. in English translated to 3 pp. in French, 4 full-page illustrations of living material).

DODD, F.P. Notes on the great Australian Cossidae. (5 pp. in English, then translated into 6 pp. in French, 7 full-page photographs of tropical Queensland scenery and people).

OBERTHÜR, C. Les *Xyleutes* d'Australie. Notes critiques et descriptions de trois Espéces nouvelles (11 pp., accompanied by 25 full-page plates of 'Les Grands *Xyleutes* australiens de la collection Ch. Oberthür').

HOULBERT, C. Sur la distribution géographique des *Xyleutes* (Lep., Zeuzeridae) et descriptions de sept éspèces nouvelles (50 pp. with photographs and maps).

HOULBERT, C. Catalogue systématiques de la tribu des Xyleutinae (144 pp.).

This work contained important contributions by Frederick Parkhurst Dodd (see above, *op. cit.*). Its principal interest is the wonderful black and white photographs of some of Australia's largest cossids collected by Dodd contemporaneously with the types of many of these moths. Many had also been identified authoritatively by Dr A.J. Turner.

Access: out-of-print, sometimes available through antiquarian book sellers: a hard to read scanned version is freely available at: https://archive.org/details/etudesdelpidop111916ober

ORD, M., [SCOTT, H. and SCOTT, H.] 1988. *Ash Island Series Volume 1. Historical Drawings of Moths and Butterflies.* Craftsman House, Roseville, NSW; 148 pp. including 56 plates.

Two differently bound versions of this work were published simultaneously, the second of which formed part of a boxed set with a matching volume of botanical illustrations by the Scott sisters.

Modern reproductions of some of the original Scott illustrations are held by the Australian Museum. The work includes a biography of the Scott family before and after their arrival in Australia. The colour plates follow, each faced with a short text giving the original and modern names of the species depicted, sometimes with additional short comments. Forty-two of the 56 plates are depictions of

moths (in one case shared with that of a skipper). Overall, the life histories of 84 species of moths are illustrated. Of the plates here reproduced five were previously published in Scott (1864) and a further three had appeared in Scott (1890–98). The remaining 34, illustrating about 70 species of moths, were first published in this work. The work represents something of a bibliographic challenge. Its title page ascribes authorship to the two Scott sisters (with no mention of Alexander Walker Scott) yet the actual work has been written, assembled and seen to publication by Marion Ord, appearing some 88 years after the death of the younger sister, Helena.

Access: out-of-print, available through second-hand book-dealers. Available in major libraries.

RICHARDSON, B. 2008. *Mothology: Discover the Magic.* LeapFrogOz Kuranda Kreations, Kuranda, Queensland; 66 pp.

A unique popular volume with photographs of more than 370 species of live moths from the Atherton Tablelands, Queensland, with carefully verified identifications. It is exceptional and charming in that it also includes a section of computer generated images created with and around photographs of moths.

Reviews:
Edwards, E.D. 2008. *Myrmecia* **44**: 26.
Hendry, P. and Hughes, L. 2008. *Metamorphosis Australia* **#51**:
Mackey, P. 2008. *Richmond Birdwing Recovery Network Newsletter* **13**: 21–23.
Access: in print, available from the author.

RICHARDSON, B. 2015. *Tropical Queensland Wildlife from Dusk to Dawn. Science and Art.* LeapFrogOz Kuranda Kreations, Kuranda, Queensland; 348 pp.

In spite of its title, this extraordinary book is principally about moths (215 of its 348 pages). Building on the author's earlier work (*op. cit.* above), over a 1000 species of carefully identified, superb photographs of living adult moths from the North Queensland rainforests are presented. Like the preceding book the moth images are interspersed with Escheresque artwork by the author derived from some of the images (see, for example, Fig. 10). The moth images are complemented by others of butterflies, other arthropods, vertebrates and, even, a few flowers. The images are organized by family although the newer classification of the Noctuoidea (*cf.* Zahiri *et al.*, 2011) is not used. The photographs, although carefully labelled with the scientific (and common, where appropriate) names of their subject matter, have no accompanying text. The volume does, however, conclude with a thoughtful essay on communicating the essence of evolution to non-scientific audiences that deserves to be widely read. Richardson does not challenge current views on how biological evolution works but does take popular writers to task as to how they represent the science. His views on the concept of mimicry, however, are less orthodox. The book is probably the most comprehensive available resource for identifying the moths of the Queensland Wet Tropics. The work is discussed at length by Kitching (2020a).

Review:
Monteith, G.B. 2016. *Metamorphosis Australia* **82**: 32–35.
Access: in print, available from the author.

ROBINSON, G.S. and NIELSEN, E.S. 1993. *Tineid Genera of Australia (Lepidoptera). Monographs on Australian Lepidoptera. Volume 2*. CSIRO Publishing, Melbourne; xvi + 344 pp.

This was the second volume to appear in the *Monographs* series and the first to adopt the top-down, genus level approach used in several subsequent volumes (Common, 1994–2000; Horak, 2006; *op. cit.*). In this fashion it created an authoritative framework for dealing with the approximately 370 species of Australian tineids, only 137 of which were named at the time of the book's publication. The work recognised 44 genera of which five were erected as new in the volume. Representatives of each genus are illustrated in *habitus* photographs in black and white accompanied by a range of genitalia, wing venation, leg morphology and other supporting images. This is one of a number of seminal contributions on the Tineidae by the late Gaden Robinson (Robinson, 2009; see commentary in Kitching, 2020b).

Review:
Scoble, M. 1994. *Journal of Natural History* **28**: 971–972.
Access: out-of-print, available as an e-Book from CSIRO Publishing, commonly available through used booksellers.

SCOTT, A.W., SCOTT, H. and SCOTT, H. The body of work produced by Alexander Walker Scott (1800–1883) and his daughters, Harriet (1830–1907) and Helena (1832–1910), appeared in two early, lavishly illustrated, books on Australian Lepidoptera. The Scotts' work was 'rediscovered' by Nancy Gray in the 1970's (Gray, 1976) and has subsequently received considerable attention for its science, art, and for the involvement of the two daughters in the nascent scientific work of the nineteenth century colony. Walker Scott and his daughters lived for many years on Ash Island on the Hunter River where Walker had taken up a large grant of land in 1831. He had trained his two talented daughters who became first-class naturalists and illustrators. Walker Scott himself was a talented artist and friend of the great animal artist, Edwin Landseer, in England. A pencil sketch of A.W. Scott by Landseer is in the Art Gallery of New South Wales (Gray 1976, Ord 1987, Finney 2018). On Ash Island, the Scotts made extensive life-history studies of the local Lepidoptera. Their conjoint works are now remembered and revered principally for their illustrations. Walker Scott was quoted by Finney (2018) as saying 'My family take an equal part with myself in all matters connected with natural history'. Each species depicted has its life-history described with appropriate food plants with pencil drawings of fine entomological detail appended. The life history paintings frequently had local landscapes as backgrounds copied by the Scott sisters (with acknowledgement) from the works of local artists such as Conrad Martens and Samuel Perry (Finney 2018). The fine illustrations were first produced as line drawings then engraved, principally by the

Scott sisters, on stone from which they were printed. These printed line images were coloured subsequently by professional colourists. The entire Scott oeuvre was purchased by the Australian Museum in 1884. Only a total of 21 of these life-history plates were included in the two contemporary volumes produced by the Scotts. Others have appeared in Finney (2018), Ord (1987) and Braby and Olsen (2011). Some of the paintings of Lepidoptera by Scott and his daughters remain unpublished but have been included in exhibitions held at the Museum in 2011 ('Beauty from Nature') and 2017 ('Transformations'). The exhibited but unpublished material includes, for example, illustration of the life histories of *Sauris* sp. (Geometridae) and of *Scorpiopsis pyrobola* (Depressariidae): both of considerable scientific merit. The Scott bibliography is further complicated by a trove of sets of prints from the published Scott volumes (see below) that were sold by the Museum in the 1970's. The Museum also made available sets that had been coloured by Museum artist, Lorraine Foster. One such framed set is in the library of the Australian Museum. The antiquarian bookseller, Kenneth Stewart, bought many of the uncoloured sets, arranged for them to be coloured by an unknown artist, bound and sold (L. Willan, personal communication). We have been unable to locate any of these 'modern' issues.

The two original Scott volumes are as follows.

SCOTT, A.W. 1864. *Australian Lepidoptera and their Transformations drawn from the Life by Harriet and Helena Scott; with Descriptions, General and Systematic.* Volume 1. John van Voorst, London; 30 pp., 9 plates.

Scott's first volume was, apparently, ready for publication up to 13 years before its actual appearance. Biologist, W. Swainson, reviewed it enthusiastically in the *Sydney Morning Herald* of August 30th 1851 when, apparently, it was envisaged as the first of a multi-volume set covering all known Australian Lepidoptera (Finney, 2018). Swainson alludes, for instance, to a 'Plate 52' depicting the Richmond Birdwing: in the event no more than 21 plates appeared in Scott's two volumes. Other previously unpublished plates, including that of the birdwing butterfly, were later included in Ord (1988) and Braby and Olsen (2011). Volume 1 was eventually published in London by John van Voorst in 1864 (thereby depriving Scott of priority for at least three species which had been described by others in the interim). This volume includes just nine plates. These were executed by his daughters with entomological details added, in part at least, by Scott himself and his stepdaughter, Frances Stirling, acting as research assistant (Finney, 2018). The plates describe the life-histories of 21 species of moths. The species covered included Saturniidae (Plate 1, 2 species, including *Antheraea* (now *Opodiphthera*) *eucalypti* Scott), Hepialidae (Plate 2, 2 spp., including *Charagia* (now *Aenetus*) *splendens* Scott; Plate 4, 1 sp.), Oecophoridae: Xyloryctinae (Plate 3, 4 spp., including *Cryptophasa immaculata* Scott, *C. bipunctata* Scott and *C. spilonota* Scott), Notodontidae (Plate 5, 2 spp., including *Cerura australis* Scott), Limacodidae (Plate 6, 4 spp., including *Doratifera casta* Scott and *Apoda* (now *Eloasa*) *infrequens* Scott), Anthelidae (Plate 7, 1 sp.), Noctuidae: Agaristinae (Plate 8,

2 spp.) and Psychidae (Plate 9, 4 spp., including *Oecinea* (now *Sentica*) *felderi* Scott, *O.* (now *Conoeca*) *guildingi* Scott and *O.* (now *Oecobia*) *frauenfeldi* Scott). Figure 6 is a reproduction of Plate 7 from this volume. The volume was lithographed and printed in Sydney but the published run of 200 copies was coloured in London by professional colourists using the original paintings as colour guides. Twenty-five of these coloured copies were returned to New South Wales (Finney, 2018) along with the original artworks.

Access: Print copies are held in most State Libraries and Museums. A freely accessible, digitised version of the copy held by the Australian Museum is available at: http://biodiversity.org/item/110617—curiously, this scan includes only pages 1–30 (of 36), but does include all the plates. The text descriptions of *Oecinea guildingi and O. frauenfeldi* are, accordingly, omitted, although these are illustrated in Plate 9.

SCOTT, A.W. 1890–98. *Australian Lepidoptera and their Transformations by the late Alexander Walker Scott; with illustrations drawn from the Life by his Daughters, Harriet Morgan and Helena Forde.* Volume 2. Australian Museum, Sydney. (Edited and revised by Helena Forde and Arthur Sydney Olliff).

This second 'Scott' volume was prepared for publication after Walker Scott's death by Helena Forde (*neé* Scott) and Arthur Olliff. Nomenclature was updated and current information, where available, incorporated. Hence, most of the names indicated at the foot of the plates were updated and synonymised in the text in line with the knowledge of the day. Sadly, this meant that the only species for which Scott might have laid claim as author in this volume, *Selidosema* (now *Cleora*) *gilva,* had been described as *Boarmia decisaria* by Francis Walker (Walker, 1866). The work appeared in four parts published in 1890 (18 pp., 3 plates), 1891a (8 pp., 3 plates), 1891b (8 pp., 3 plates) and 1893 (10 pp., 3 plates), respectively, with the overarching title page published in 1898. The text pages are numbered independently of the 1864 volume whereas the plates continue the 1864 sequence (hence, Plates 10–21). Although printed and published in Sydney the plates were hand-coloured in London. By this date such expertise was rare. Nevertheless, it is recorded (Finney, 2018) that at least some of the coloured plates were over-washed and recoloured by Helena Forde after their arrival back in Sydney to correct the efforts of the London colourists. Seven of the eleven plates illustrate the life cycles of moths including species of Sphingidae (Plate 10, 1 species), Erebidae: Erebinae (Plate 11, 1 sp.), Hepialidae (Plate 11, 1 sp.), Saturniidae (Plate 13, 1 sp.), Noctuidae: Agaristinae (Plate 15, 4 spp.), Erebidae: Erebinae (Plate 18, 4 spp.), Anthelidae (Plate 19, 2 spp.) and Geometridae: Ennominae (Plate 21, 4 spp.).

Access: A freely accessible, digitised version of the copy held by the National Library of Australia is available at: http://nla.gov.au/nla.obj-52963266

SEITZ, A. 1907–1940. *Die Großschmetterlinge der Erde*. Alfred Kernen Verlag, Stuttgart.

Adalbert Seitz (1860–1938) produced this iconic, monumental series of volumes describing and illustrating the Macrolepidoptera of the World as regionally organized volumes produced from 1907 to 1940, with supplements produced subsequently until 1954. The first four volumes described the Palaearctic fauna ('Division 1'), the rest ('Division 2') being devoted to what he called *Die exotischen Großschmetterlinge*. Seitz published the series in short signatures eventually building to 16 massive volumes totalling many thousands of pages and a commensurate number of spectacular plates. His mostly first-rate illustrations were produced using colour lithography, a cutting-edge technology in 1912. Fig. 5 is an example from one of the Indo-Australian volumes. Seitz's life's work was gradually overtaken by two world wars and the evolution of newer printing technology. The full extent of his publishing ambitions was never achieved. The entire work was originally intended to be produced in parallel in German, English and French versions (many of which appeared) which, combined with the original publication as a part-work, has made the exact dating of the works a bibliographic nightmare. Griffin (1936) resolved the dates of issue of the various parts for the German (first) editions up to 1935 (i.e. the first part of Volume 16) based on their dates of receipt by the library of the Natural History Museum in London. Australian species are included in Volumes 9 to 12 as part of the 'Indo-Australian' fauna. Volume 9 is devoted to butterflies and the remaining three to moths. For volume 10 the English versions are contemporaneous with the German ones (see below). According to Griffin (1936) exact dates for the English versions of Volumes 11 and 12 are uncertain (although the later parts, 265–568, of Volume 12 were received in London between 1922 and 1934 and often have a date of publication printed on them).

Access: long out-of-print and extremely expensive in the antiquarian marketplace. Scanned versions are available for free download at: https://www.biodiversitylibrary.org

So, the three volumes on moths of special interest to Australian workers, in order of the appearance of their earliest parts, are as follows.

SEITZ, A. 1916–1935. *Die exotischen Großschmetterlinge, die indo-australischen Spanner.* Band 12. [translated as: *The Macrolepidoptera of the World, Division II: Fauna Exotica. The Macrolepidoptera of the Indo-Australian Fauna. Volume XII. Geometridae*]. Alfred Kernen Verlag, Stuttgart; 356 pp., 41 plates.

SEITZ, A. 1924–26. *Die exotischen Großschmetterlinge, die indo-australischen eulenartigen Nachtfalter.* Band 11. [translated as: *The Macrolepidoptera of the World, Division II: Fauna Exotica. The Macrolepidoptera of the Indo-Australian Fauna. Volume XI. Noctuiform Phalaenae*]. Alfred Kernen Verlag, Stuttgart; 496 pp., 57 plates.

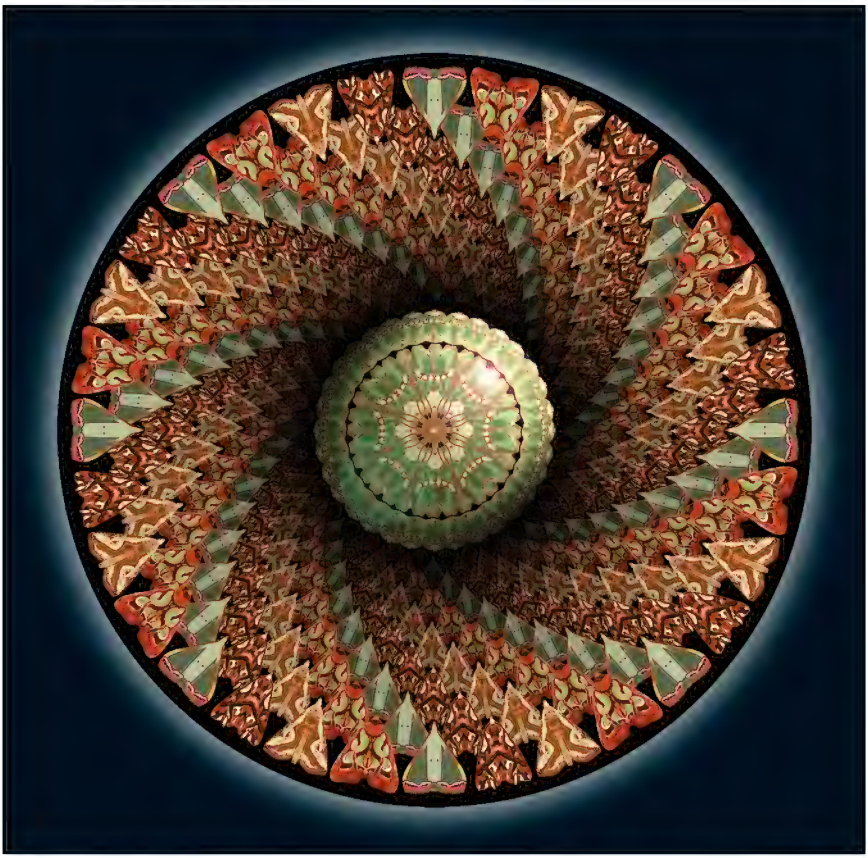


Fig. 10. Artwork based on moth images: 'Spiralling to Anassodes' from *Tropical Queensland Wildlife from Dawn to Dusk* by Richardson (2015).

SEITZ, A. 1930–34. *Die exotischen Großschmetterlinge, die indo-australischen Spinner und Schwärmer.* Band 10. [translated as: *The Macrolepidoptera of the World, Division II: Fauna Exotica. The Macrolepidoptera of the Indo-Australian Fauna. Volume X. Bombyces and Sphinges*]. Alfred Kernen Verlag, Stuttgart; 909 pp., 104 plates.

SIMONSEN, T.J. 2018. *Splendid Ghost Moths and their Allies. A Revision of Australian* Abantiades, Oncopera, Aenetus, Archaeoaenetus *and* Zelotypia *(Hepialidae). Monographs on Australian Lepidoptera. Volume 12.* CSIRO Publishing, Melbourne; x + 300 pp.

This twelfth volume in the *Monographs* series complements the first (Nielsen and Kristensen, 1989, *op. cit.*) in returning to the 'primitive' family, the Hepialidae. This volume covers the 'hepialine' hepialids (*s. s.*): that is, the paraphyletic group

which show typical, so-called, hepialine wing venation. Of more interest, perhaps, is that it covers the spectacular giant ghost moths that have attracted the attention of workers on the Australian moth fauna from Lewin (1805, *op. cit.*) onwards. The work describes or redescribes 70 species in five genera, 14 species and a genus being described for the first time. All species are illustrated in colour with accompanying black and white illustrations of general morphology and genitalia, together with distribution maps. The appearance of this volume leaves only the oxycanine genera of hepialids (*ca* 47 species) and two 'primitive' species (often placed in separate families) without modern treatment.

Reviews:
Edwards, E.D. 2018. *News Bulletin, Entomological Society of Queensland* **46**: 36–37.
New, T.R. 2018. *Austral Entomology* **57:** 369–370.
Access: in print, available from the publishers.

SWINHOE, C. 1892. *Catalogue of the Eastern and Australian Lepidoptera Heterocera in the collection of the Oxford University Museum, Part 1. Sphinges and Bombyces.* Clarendon Press, Oxford; viii + 324 pp., 8 plates.

Swinhoe's checklists are principally useful in that they confirm the location (at least at the time of his writing) of the primary (and associated) types of many earlier entomologists, such as the prolific Francis Walker, described from material collected by some of the great names of the day—most notable of whom was undoubtedly Alfred Russel Wallace. Some new species are described including Australian taxa. The text associated with each species is minimal summarising nomenclature and distribution. The work includes many species that occur in Australia, and includes eight lithographic plates illustrating representative species.

Access: Copies are held by the State Library of Queensland, Fryer Library, University of Queensland, CSIRO Black Mountain Library, etc. Freely available for electronic download at: https://www.biodiversitylibrary.org/page/11077340

SWINHOE, C. 1900. *Catalogue of the Eastern and Australian Lepidoptera Heterocera in the collection of the Oxford University Museum, Part II. Noctuina, Geometrina and Pyralidina. Pterophoridae and Tineina* by Lord Walsingham and J.H. Durrant. Clarendon Press, Oxford; vi + 630 pp., 8 plates.

This is the delayed continuation of the 1892 volume covering the remaining taxa. Again, illustrated with eight fine lithographic plates. Swinhoe's Preface to this volume includes the wonderful (and familiar) *cri de coeur* "*Many years ago, some one, not acquainted with the types in the Hope collection of moths, weeded out many faded-looking specimens and deposited them in old drawers and cases now in the loft at the top of the building. I think I have now searched through every case and box...*". At least they didn't throw them out.

Review:
Anonymous. 1900. *Annals and Magazine of Natural History* (7) **6**: 506–507.
Access: Copies are held by the State Library of Queensland, Fryer Library,

University of Queensland, CSIRO Black Mountain Library, etc. Freely available for electronic download at: https://www.biodiversitylibrary.org/item/75443

TARMANN, G.M. 2004. *Zygaenid Moths of Australia. Monographs on Australian Lepidoptera. Volume 9*. CSIRO Publishing, Melbourne; viii + 248 pp.
After the sphingids and saturniids, the Zygaenidae probably attract the most global interest of any moth family. This no doubt reflects their diurnal habits and (often) bright colouration. They are not well represented in Australia where only the subfamily Procridinae occurs. Tarmann, in this volume, reviews the group exhaustively, describing and illustrating 43 named species (of which 21 species are described as new). He also notes eight additional putative species (in the large genus *Pollanisus*) that await further material before being named. This is the only volume in the *Monograph* series to be illustrated by paintings, superbly executed by Frantisek Gregor, bringing out the subtle iridescences and scale patterns by which the adults may be recognised (see, for example, Tarmann's Plate 1 reproduced here as Fig. 7). These are complemented by the 'usual' black and white illustrations of genitalia.

Reviews:
Moreno, A.V. 2005. *Revista de Lepidopterologia* **33**: 196.
Simonsen, T.J. 2011. *Journal of the Lepidopterists' Society* **65**: 202–203.
Access: out-of-print, available as an e-Book from CSIRO Publishing, commonly available through used book sellers.

ZBOROWSKI, P. and EDWARDS, E.D. 2007. *A Guide to Australian Moths.* CSIRO Publishing, Melbourne; x + 214 pp.

This richly illustrated book provides a short introduction to all but the smallest and most obscure moth families occurring in Australia. It is exceptional in that almost all of the photos of adults are of living individuals capturing the, often characteristic, resting postures of each group. It provides non-technical diagnoses for each family and, as such, is a first-class introduction to the neophyte (and others). Published in 2007, it accordingly retains the 'old' concept' of the Gelechioidea, Pyraloidea and Noctuoidea (see comments on Nielsen, Edwards and Rangsi, 1996, *loc. cit.*, above). The book was reprinted in 2017 with some corrections, but not up-dated.

Reviews:
Marriot, P. 2007. *Victorian Naturalist* **124**: 279.
Mattoni, R. 2009. *Journal of Research on the Lepidoptera* **41**: 85.
New, T.R. 2008. *Journal of Insect Conservation* **12**: 573–574.
Access: The reprinted version is available in print and as an e-Book, available from the publishers and from www.amazon.com.

WORLD CATALOGUES

This list, which may well not be complete, directs students to the various global check-lists, catalogues of names and summaries of classifications of groups of moth families. Needless to say, the Australian fauna, or parts of it, is embedded within these treatments. Any future revisionary work can (sometimes laboriously)

trace taxonomic changes in nomenclature through time using these works. Nevertheless, beginning with the Nielsen, Edwards and Rangsi (1996), Australia-specific, checklist discussed above (*loc. cit.*) is highly recommended.

BALDIZZONE, G., LANDRY, J.-F. and WOLF, H. van der. 2006. *World Catalogue of Insects. Volume 8. Coleophoridae Coleophorinae (Lepidoptera).* Apollo, Stenstrup; 215 pp.

BRIDGES, C.A. 1993. *Catalogue of the Family-Group, Genus-Group and Species-Group Names of the Sphingidae of the World.* Urbana, Illinois, Privately Published, 13 Fascicles each separately paginated.

BROWN, J.W. 2005. *World Catalogue of Insects. Volume 5. Tortricidae (Lepidoptera).* Apollo, Stenstrup; 741 pp.

FLETCHER, D.S. 1979. *The Generic Names of the Moths of the World. Volume 3. Geometroidea.* British Museum (Natural History), London; xx + 243 pp.

FLETCHER, D.S. and NYE, I.W.B. 1984. *The Generic Names of the Moths of the World. Volume 4. Bombycoidea–Zygaenoidea.* British Museum (Natural History), London; xiv + 192 pp.

FLETCHER, D.S. and NYE, I.W.B. 1984. *The Generic Names of the Moths of the World. Volume 5. Pyraloidea.* British Museum (Natural History), London; xvi + 185 pp.

GENERA INSECTORUM. 1902–1970. Edited (1902–1970) by P. Wytsman, Various Publishers: Verteneuil and Desmet (later Louis Desmet-Verteneuil), Brussels (1902–1955), Edition Mercurites, Brussels (1967–1970). Fascicles numbered 1–219. An index is available on-line at: https://www.biodiversitylibrary.org/bibliography/45481#

Issues relevant to the Australian moth fauna are as follows.

Fascicle 57. Rothschild, W. v. and Jordan, K. 1907. Lepidoptera Heterocera: Fam. Sphingidae. 157 pp., 8 plates.

Fascicle 100. Meyrick, E. 1910. Lepidoptera Heterocera (Pyrales): Fam. Pterophoridae. 22 pp., 2 plates.

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Part 7. Zeray, H. 1912. *Syntomidae*. 179 pp.

Part 8. Prout, L.B. 1912. *Geometridae: Brephinae, Oenochrominae*. 94 pp.

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Parts 12, 18, 21, 23, Wagner, H. 1913–19. *Sphingidae*. 420 pp.
Part 13. Meyrick, E. 1913. *Carposinidae, Heliodinidae, Glyphipterygidae*. 53 pp.
Part 14. Prout, L.B. 1913. *Geometridae: Hemitheinae*. 192 pp.
Part 15. Dalla Torre, K.W. von 1913. *Castniidae: Castniinae, Neocastniinae, Pemphigostolinae*. 28 pp.
Part 16 (*partim*). Dyar, H.G. and Strand, E. 1913. *Megalopygidae, Dalceridae, Epipyropidae*. 35 pp.
Part 17. Meyrick, E. 1913. *Pterophoridae*, *Orneodidae*. 44 pp.
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Part 29. Dalla Torre, K.W. von 1923. *Cossidae*. 63 pp.
Part 30. Dalla Torre, K.W. von 1924. *Epiplemidae, Uraniidae*. 57 pp.
Part 31. Dalla Torre, K.W. von and Strand, E. 1925. *Aegeriidae*. 282 pp.
Part 32. Eecke, R. van 1925. *Cochlidionidae, Limacodidae*. 81 pp.
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Part 34. Dalla Torre, K.W. von and Strand, E. 1929. *Psychidae*. 215 pp.
Part 49. Gaede, M. 1931. *Drepanidae*. 60 pp.
Part 52. Gaede, M. 1932. *Aganaidae*. 39 pp.
Part 59. Gaede, M. 1934. *Notodontidae*. 351 pp.
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Part 62. Bryk, F. 1934. *Lymantriidae*. 441 pp.
Part 67. Busek, A. 1935. *Stenomidae*. 73 pp.
Part 70. Schüssler, H. 1936. *Syssphingidae*. 230 pp.
Part 73. Collier, W.A. 1936. *Lasiocampidae*. 484 pp.
Part 79. Gaede, M. 1937. *Gelechiidae*. 630 pp.
Part 82. Bryk, F. 1937. *Arctiidae: Callimorphinae, Nyctemerinae*. 126 pp.
Part 84. Klima, A. 1937. *Pyralididae: Scoparinae, Nymphulinae*. 226 pp.
Part 88. Gaede, M. 1938. *Oecophoridae I*. 208 pp.
Part 89. Klima, A. 1939. *Pyralididae: Pyraustinae I*. 224 pp.

LEPIDOPTERORUM CATALOGUS (NEW SERIES), (Edited by J.B. Heppner)

This series was established in the style of the original German-published *Lepidopterorum Catalogus*. Its thoroughly laudable goal was to update taxonomy, nomenclature and bibliography for each of the 124 families supported in Heppner's (1998) classification. Poole's (1989) massive and important work on the Noctuidae (*sensu lato*) started the series off well. All that appears to have been

published subsequently are a limited number of accounts of very small families. Those relevant to Australia are as follows:

Fascicle 47. Gaedike, R. 1996. *Epermeniidae.* Association for Tropical Lepidoptera, Gainesville; 16 pp.

Fascicle 61. Heppner, J.B. 1998. *Tineodidae.* Association for Tropical Lepidoptera, Gainesville; 8 pp.

Fascicles 116–118. Poole, R.W. 1989. *Noctuidae.* 3 Volumes. Brill, Leiden; 1314 pp.

LEWIS, J. and SOHN, J.-C. 2015. *World Catalogue of Insects. Volume 12. Lepidoptera: Yponomeutoidea 1 (Argyresthiidae, Attevidae, Praydidae, Scythropiidae and Yponomeutidae).* Brill, Leiden; xxiv + 253 pp.

NYE, I.W.B. 1991. *The Generic Names of the Moths of the World. Volume 1. Noctuoidea (part): Noctuidae, Agaristidae and Nolidae.* British Museum (Natural History), London; x + 568 pp.

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Discussion and Conclusions

The volumes discussed in this bibliography, individually and severally, serve four principle purposes for current and future students of the moths. First, a selection of the works provide primers and more advanced texts for those wishing to become familiar with the moths in general. Zborowski and Edwards (2007) and Common (1990), for example, meet these needs well. Second, the volumes capture the more than two centuries of work on the Australian moth fauna, an appreciation of which is essential for current research. As a third purpose, the works provide the taxonomic background and current monographs that underpin any future serious systematic work. They provide exemplars of how such work should be done and allow researchers to identify gaps and uncertainties in the families covered, or indeed, within the whole moth fauna. Finally, some of the

works provide illustrated guides to aid identification of the specimen in hand (or photograph) as part of survey work, or general interest.

The first three of these purposes—as general introductions, historical documents or 'deep' taxonomy—are well served by the works currently available. For formal taxonomic treatments we still have many significant gaps in our knowledge but the *Monograph* series, for example, will continue to provide an outlet for the products of serious workers on particular groups. Of course, we wish there were more such workers but there are works in preparation and we can anticipate a steady trickle of these in the future.

The real challenge facing any moth worker remains identifying specimens. Some of the works listed will aid in this regard: the Sphingidae, Zygaenidae, Noctuidae: Heliothinae, and most Hepialidae, for example, are now covered by well-illustrated works. Victorian students of the macrolepidoptera can hope to identify a growing proportion of their moth fauna through the on-going *Moths of Victoria* series. Other richly illustrated works such as Common's earlier works (Common 1963, 1990) and comparable regionally focussed works such as those by Braby *et al.* (2018), Richardson (2008, 2015) and McQuillan *et al.* (2019), will aid in identification but only if your specimen happens to belong to one of the species that these authors have chosen to include.

The worker wishing to identify specimens must then turn to two other sets of resources: museum collections and the internet.

Most state museums and, of course, the Australian National Insect Collection, hold very large numbers of more or less well identified specimens and, generally, welcome access by serious scholars (amateur and professional). Identification of material by comparison with museum collections is laborious and often frustrating except for the rare instances when there are local curators both familiar with the collections and with the remit to assist visitors.

Identifying material using on-line resources is equally challenging. There are half a dozen websites of use to those wishing to identify Australian moths ranging from the near complete BOLD data-base of specimens that have been DNA-barcoded, to sites maintained by amateur scholars based on their own collecting and identifications. This is not the place to review these sites. It must be said, however, that in the current state of knowledge all three resources—books, collections and websites—remain essential complements to each other in the task of identification. Books remain, to us, the most useful and tangible of these tools as well as having a *presence* we find missing in electronic resources. Arguably also, they have a longevity which, we fear, will not be matched by electronic resources. The ups and downs of *Australian Moths Online*, one of the most useful websites, provide ample evidence of the likely ephemeral nature of websites. It should be appreciated, of course, that there are moths that cannot be identified from *habitus* images because photographs do not show the necessary distinguishing characters. A deep knowledge of moths is necessary to know what can and cannot be identified from images.

Fig. 11. Artwork based on moth images: Case of moths and butterflies spelling out a verse by Longfellow, from the Dodd Collection (Queensland Museum, reproduced from Monteith, 2010).

The present, past and (let us hope) future legion of moth books available for Australian workers provide an irreplaceable resource for all those interested in the Order Lepidoptera.

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PROBABLE ADULT MALE SCHAYER'S GRASSHOPPER *SCHAYERA BAIULUS* (ERICHSON, 1842) (ORTHOPTERA: ACRIDIDAE: CATANTOPINAE) FOUND IN NORTH-EASTERN TASMANIA

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Abstract

Schayer's grasshopper *Schayera baiulus* (Erichson, 1842) is one of the most rarely recorded species in Australia, with only five specimens having been previously collected. Here we describe and illustrate an adult male grasshopper which we ascribe to *S. baiulus*. If so, it is the first known example of an adult male of this species; thus we provide here a detailed description of our specimen. This description should assist with the future surveys that will be required to validate our identification and confirm the species' continued existence.

Key words: *Calliptamus*, insect conservation, rare and threatened species

Introduction

Schayer's grasshopper *Schayera baiulus* (Erichson, 1842) is an enigma among the Tasmanian Orthoptera, and arguably among the Australian fauna more generally. It was described by Erichson (1842) (as *Calliptamus baiulus*) based on three female specimens sent to him in Germany by Adolphus Schayer, who at that time was the superintendent of the Woolnorth Station property of the Van Diemen's Land Company in north-western Tasmania. Since its description, and despite some dedicated surveys, no further specimens were collected for nearly 150 years, and the location of the three collected specimens remained unknown until 1986 when they were discovered in the Zoologisches Museum of Humboldt University, Berlin (Key 1990). Two of the specimens were sent to K.H.L. Key who redescribed and illustrated the original material and erected the monotypic genus *Schayera* for Erichson's *Calliptamus baiulus*, considering it to be closely related to the mainland catantopine genera *Apotropis* Bolívar, 1906, *Azelota* Brunner, 1893 and *Perunga* Sjöstedt, 1921 (Key 1990). One of the two specimens was retained at the Australian National Insect Collection, Canberra (ANIC) and the other was returned to Berlin. Because no specimens had been found since its description, Key (1990) regarded Schayer's grasshopper as a highly endangered species or possibly extinct.

Then, in 1988 two specimens were collected in two widely separated locations: a dead male nymph was recognised by K.H.L. Key amongst grasshoppers collected on his behalf by E.J. Zurcher and C.A.B. Gilbert near Rushy Lagoon in far north-eastern Tasmania; and a live female nymph was found by K.H.L. Key at Cape

Fig. 1. Locations of probable adult male Schayer's grasshopper (red square) collected in 2018 and two nymphal Schayer's grasshoppers collected in 1988 (yellow triangles). The locations of the three specimens identified by Erichson (1842) are not known, with 'Terra v. diem. [i.e. Tasmania]' the only location information printed on the labels (Key, 1990).

Grim in far north-western Tasmania (Key 1991) (Fig. 1). A note was added in proof to Key's (1990) paper stating that two nymphs had been discovered. The Cape Grim female nymph was reared to adulthood and, together with the male nymph, enabled a fuller description of the species (Key 1991).

Subsequent surveys by K.H.L Key and P.B. McQuillan (Key 1991) and by several others (including ourselves) had failed to locate further specimens until one of us (SG) found a male grasshopper in north-eastern Tasmania, only a few kilometres from Rushy Lagoon, which did not fit the description of other grasshoppers found in Tasmania. Here we describe and illustrate this specimen and make a case that it is most likely to be an adult male Schayer's grasshopper so that it will assist future searches for this grasshopper. We also provide a brief description of the habitat where it was collected.

Material and methods

Collecting details and description of habitat. The specimen (now in the TMAG collections, with registration number F96436) was collected (by SG) on 9 Nov. 2018 while sweep-netting in the dunes behind Lemons Beach (Fig. 2), between Petal Point and Cape Portland, at -40.7725°, 147.9555°. This area comprises a combination of mobile and stable sand-dunes of aeolian origin. The vegetation consists of an overstorey of *Acacia longifolia* subsp. *sophorae*, *Leucopogon*

Fig. 2. Dunes behind Lemons Beach where the probable adult male Schayer's grasshopper was collected in a sweep net (image by S. Grove).

parviflorus and *Leptospermum laevigatum*, with an understorey of grasses, herbs and small shrubs, including the non-native grasses *Ammophila arenaria* and *Holcus lanatus*, the native grass *Spinifex sericeus*, the sedge *Ficinia nodosa*, the herbs *Stellaria pallida*, *Crassula decumbens* and *Daucus glochidiatus*, the scandent herb *Tetragonia implexicoma*, and the shrub *Olearia axillaris*. The hollows between the dunes bear a covering of *Lepidosperma* species sedges and *Juncus* species rushes, with occasional ephemeral to semi-permanent brackish-water pools and lagoons. Though the dunes are fenced from adjacent grazing land, there was evidence (dung and hoof-prints) of recent incursions by cattle. Eastern grey kangaroos, Bennett's wallabies, common wombats and European rabbits also frequent the dunes.

Description of specimen. The specimen was described (by MD) with the aid of a Wild dissecting microscope. Body measurements (in mm) were recorded at 6.4 times magnification with a graticule in the eye-piece. Images of the specimen (Fig. 3) were compared (by YNS) at the ANIC with other acridids in the collection, including the male nymph of *S. baiulus* collected from Rushy Lagoon in 1988 (Fig. 4).

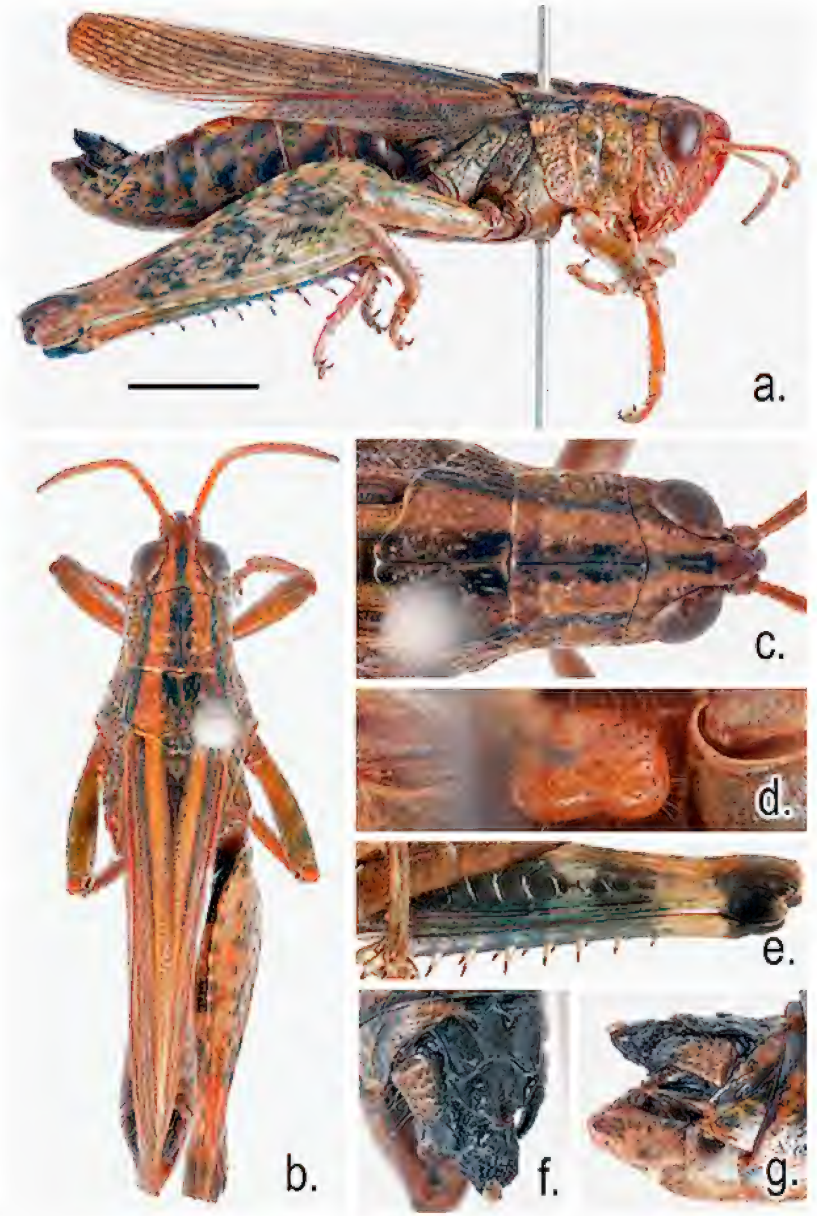

Fig. 3. Probable male *Schayera baiulus* (Erichson): (a) lateral view, scale bar: 5 mm (b) dorsal view, (c) dorsal view of fastigium and pronotum, (d) ventral view of prosternal process, (e) inner hind femur, (f) furcula, supra-anal plate and cercus (g) lateral view of terminal segments. Vegetated dunes behind Lemons Beach, 9 Nov. 2018. S. Grove.

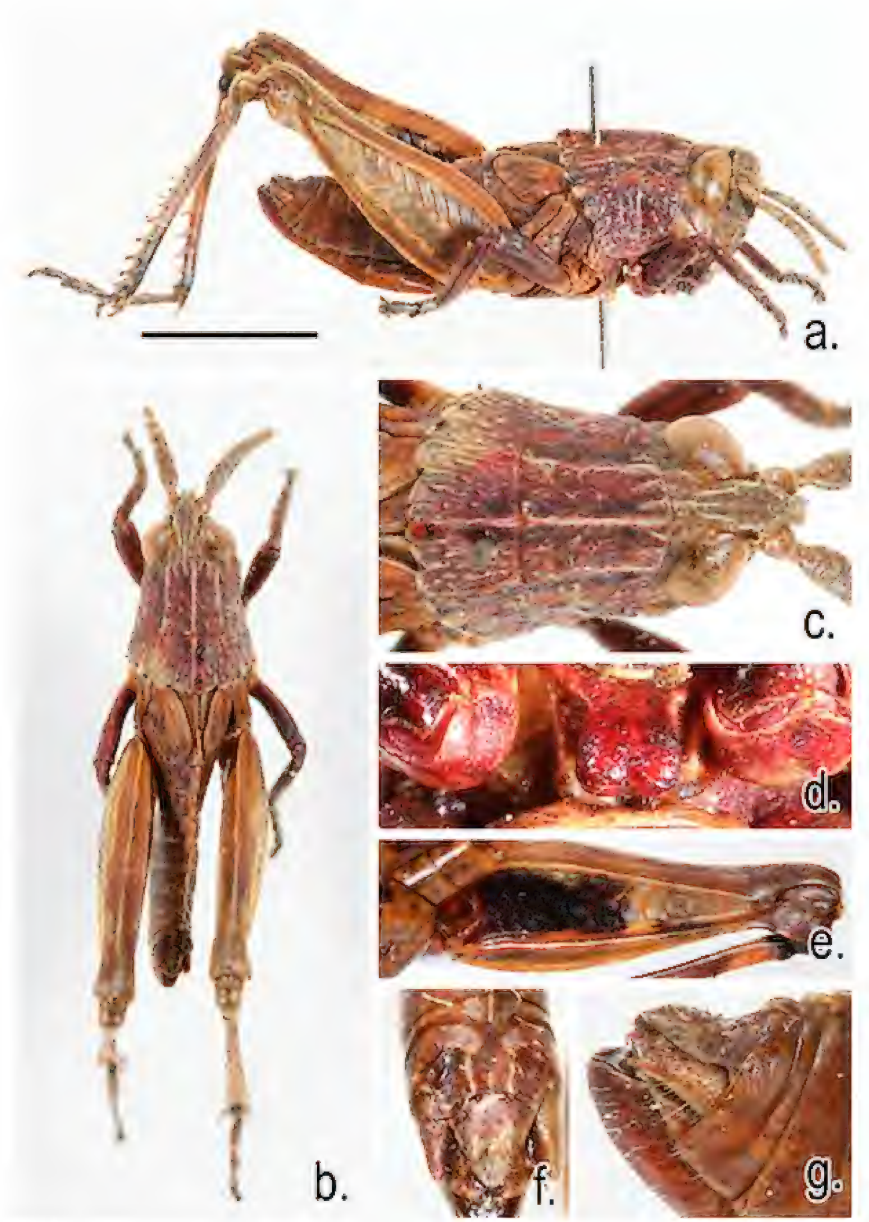

Fig. 4. Immature male *Schayera baiulus* (Erichson), probably an antepenultimate nymph: (a) lateral view, scale bar: 5 mm (b) dorsal view, (c) dorsal view of fastigium and pronotum, (d) ventral view of prosternal process, (e) inner hind femur, (f) furcula, supra-anal plate and cercus (g) lateral view of terminal segments. 2.5 km west of Rushy Lagoon, 9 Oct 1988. C.A.B. Gilbert and E.J. Zurcher.

Results

Description of specimen (refer to Fig. 3a–g). Antenna somewhat flattened, almost twice as wide as deep (Fig. 1a). Head with fastigium slightly descending, with a short median carina extending onto occiput; broadly triangulate, impressed, narrow, sharp. Pronotum with many tubercles; anterior margin produced slightly forward; posterior margin rounded, produced, somewhat scalloped; median carina heavy, cut only by the third sulcus; lateral carina prominent, nearly continuous, apically divergent, cut by the second and third sulci (Fig. 3c). Prosternal process strongly inflated, rounded and medially indented (Fig. 3d). Thorax bearing two fully formed wings; brown with a pale, V-shaped, dorsal stripe (similar pattern to *Apotropis tricarinata* (Stål, 1878)); a thin, reddish ("testaceous"), stripe present laterally in area bounded by Pcu and V1 (Fig. 3b) (this stripe is also clearly seen in the image of the paralectotype female in Key (1990)). Femur III internally mostly black; distal end with a straw-coloured band about 1.5 mm wide; whitish and blue/green marks are present anterior to the straw-coloured band; externally mostly brown with black markings (Fig. 3e). Tibia III internally steel-blue with greenish tinge; straw-coloured band about 1.5 mm wide at proximal end; this tibia bears spines up to 0.9 mm long that are light brown and black-tipped, with 8 external and 9 internal. Tarsus III crimson dorsally, brown ventrally. Legs I and II brown with dull green and dark brown markings. Abdomen brown with similar-shaped black markings repeated on each segment. Furcula with arms short, black-tipped (Fig. 3f). Supra-anal plate in proximal third with a longitudinal ridge extending caudad from each arm of the furcula. Cercus short, apex rounded, curved inwards (Fig. 3g). Body measurements (in mm): body length = 24.4, head length = 2.8, ocular interspace = 1.1, pronotum length = 6.25, greatest width of pronotum between ventrocaudad angles = 3.9, length of femur = 15.0, greatest breadth of femur = 5.8, length of tegmen = 16.4, greatest breadth of tegmen = 3.0.

Discussion

The specimen described in this paper does not resemble any specimens previously collected in Tasmania or any specimens held in the ANIC. This leaves two feasible possibilities: 1) that this is a new species; or 2) that this is an adult male *Schayera baiulus*. We feel that the most parsimonious explanation is 2), based not only on the proximity of the collecting locality to Rushy Lagoon but also on the following features of the specimen:

- Large size
- Fastigium broadly triangulate, impressed, narrow and sharp
- Presence of many tubercles on pronotum surface, which is cut by the third sulcus, and with lateral and median carinae prominent
- Broad similarity of colour pattern on fastigium and pronotum to those in images of the two existing specimens
- Presence of testaceous stripe on tegmen in area bounded by Pcu and V1
- Similarity of prosternal process to that shown in Rentz *et al.* (2003) (i.e. inflated, blunt and indented)
- Presence of strong furcula

- Presence of longitudinal ridges on supra-anal plate
- Similarity of the supra-anal plate and furcula of the collected specimen to those on the male nymph from Rushy Lagoon

Features not entirely consistent with the description by Key (1990, 1991)

- Median carina on pronotum not especially arched
- Antennae are not strongly flattened. Nevertheless, the antennae are somewhat flattened, and in many acridids there is a trend for progressively less flattening from nymphal stage to adult (e.g. *Goniaea australasiae* (Leach, 1814))
- The shape of the posterior edge of the pronotum is somewhat different, but again this can vary between nymphs and adults.
- Pronotum and legs I and II are not strongly tinged with dull red. However, Key (1991) noted that this was not fully symmetrical in the male nymph and considered that it may have been a consequence of over-long retention in the (cyanide) killing-bottle.

Confirmation that this specimen does indeed represent an extant population of Schayer's grasshopper will require further collection of both male and female specimens. By providing a description and photographs of this specimen we hope to facilitate further searches for this elusive species, which is listed as Endangered on Tasmania's *Threatened Species Protection Act 1995.*

Acknowledgements

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NOTES ON THE GENUS *IMMA* WALKER (LEPIDOPTERA: IMMIDAE) IN FIJI WITH THE DESCRIPTION OF A NEW SPECIES

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Abstract

The current knowledge of the genus *Imma* Walker, 1859 in Fiji is discussed, and a new species *I. vitiensis* **sp. n.** is described, and the adult and male genitalia are illustrated.

Key words: *Imma*, Immidae, Fiji

Introduction

The genus *Imma* Walker, 1859 currently contains over 150 described species worldwide. Seven have been recorded from Fiji. All the currently known Fijian species were described by Meyrick prior to 1938, and it appears that no further discussion of these has taken place since. They are all illustrated by Clarke (1969), including the male or female genitalia as available. The somewhat tortuous history of the genus is discussed further in the Systematics section.

In Fiji, the prevailing weather has a major influence on the native vegetation in different parts of the main island, Viti Levu. In roughly the south-east 70% this is rain forest. In the remainder it is dry grassland, known by its Fijian name talasiga (sun-burnt) which refers to the burnt, brownish colour which it takes on during the dry season. The second largest island, Vanua Levu, is much more elongated in shape, and the distinction between the two zones is less marked. The current study was restricted to light-trapping in forest locations (and adjacent areas such as suburban Suva) in the East of Viti Levu, and to a smaller extent Vanua Levu. No recording was carried out in talasiga areas. Of the current seven Fijian species, *I. chlorospila* Meyrick, 1923, *I. harpagacma* Meyrick, 1935 and *I. trachyptila* Meyrick, 1921 were described from talasiga areas, and were not found in the study. *Imma pyrophthalma* Meyrick, 1937 was described from a forest area, but was also not found. *Imma leucomystis* Meyrick, 1923, *I. autodoxa* (Meyrick, 1886) and *I. philonoma* Meyrick, 1925 were all described from forest areas, and were all found in the current study.

Additionally, three males were taken, which showed the characteristics of the genus, but could not be assigned to any existing species. The three are conspecific, and are described here as *I. vitiensis* **sp. n.** Two were taken in lowland forest in Tailevu province, at an altitude of 75 m, and one in montane forest in Naitasiri province, at an altitude of 1000m. No life history details are available for *I. vitiensis* **sp. n.**

Materials and methods

A regular programme of light trapping was carried out from 1991–1998 at various lowland forest locations in the Eastern Viti Levu provinces of Serua [18°09′S 178°01′E], Namosi [18°06′S 178°10′E], Tailevu [17°55′S 178°30′E], Savura [18°04′S 178°26′E] and in the Suva area [18°09′S 178°26′E]. A small number of

visits were also made to Cakaudrove Province in Vanua Levu [16°25′S 179°54′E]. These locations ranged in altitude from sea level to 200 m. Recording also took place in montane forest in Naitasiri Province in Viti Levu [17°43′S 178°01′E] at an altitude of 1000 m. A battery-powered trap was employed, using a 6W actinic tube as a light source. This allowed easier access to more remote locations. A small number of further visits were made up to 2013. All types of *I. vitiensis* **sp. n.**, together with genitalia slides, have been deposited in the National Museums of Scotland, Edinburgh.

Material examined other than that within the systematic component: *Imma leucomystis* Meyrick, 1923 (Fig. 1) 4 specimens: 1 ♂, 1 ♀, Namosi, 10.iii.92; 1♂, Cakaudrove, 11.ii.13; 1 ♂, Suva, 14.vi.92. *Imma philonoma* Meyrick, 1925 (Fig. 2) 1 specimen: 1 ♂, Serua, 12.iv.97. *Imma autodoxa* Meyrick, 1886 (Fig. 3) *Material examined.* 2 specimens: 1 ♂, Namosi, 12.xii.96; 1 ♂, Suva, 13.vi.92.

In addition to material examined and Meyrick's descriptions, all seven current Fijian species were illustrated by Clarke (1969). This allowed all these species to be excluded as a possible identification for *I. vitiensis* **sp. n.**

Systematics

The genus *Imma* was established by Walker (1859). He also described the single species *Imma rugosalis* Walker, the type species by monotypy. He placed the genus in the family Herminidae, now Erebidae: Herminiinae. Meyrick (1906) included *Imma* in the Plutellidae, but thereafter it was generally included by authors in the Glyphypterigidae. Heppner (1977), placed *Imma* in a new family, Immidae, type genus *Imma.* He placed Immidae in the superfamily Sesioidea. Common (1979) established the superfamily Immoidea, with Immidae as the sole member. Heppner (1982) reviewed the family and produced a world checklist.

Family Immidae Heppner, 1977

Type genus: *Imma* Walker, 1859.

Robinson *et al.* (1994) give a description of the family Immidae. They developed this to specifically highlight characters which distinguish Immidae from Tortricidae and Copromorphidae, two families whose members can be superficially very similar to Immidae. They provide drawings of typical wing venation.

Genus *Imma* Walker, 1859

Type species: *Imma rugosalis* Walker, 1859, by monotypy.

Meyrick (1906) updated Walker's brief original generic description based on almost 100 species which he included in *Imma.* Meyrick's description is used here. Salient features of this are: 'head with loosely appressed hairs, sometimes brushed upwards between antennae or erect on crown in ♂; ocelli small or absent'; 'antennae ½–⅗ , in ♂ moderately ciliated, seldom fasciculate-ciliated or bipectinated, basal joint thickened or tufted with scales, sometimes very elongate in ♂'; 'labial palpi moderately long, curved, ascending, basal joint sometimes elongate, second joint thickened with dense scales, in ♂ often laterally excurved,

sometimes long-haired above, terminal joint seldom more than half second, pointed or obtuse, in ♂ sometimes shorter or minute or aborted; maxillary palpi obsolete'; 'middle and posterior tibiae with appressed scales above, sometimes in ♂ with dense brushes of hairs beneath'. For the wing venation, nomenclature used by Robinson *et al.* (1994) has here been added to that used by Meyrick for convenience of comparison: 'fore-wings elongate, more or less dilated; 1b [1A+2A] furcate, 2 [CuA_2] from near angle, 7 and 8 [R_4 and R_5] separate or stalked, 7 [R_5] to termen, 8 [R_4] usually to termen, sometimes to apex or costa, rarely absent (coincident with 7 [R_5]), 9–11 [R_1-R_3] tolerably equidistant, no secondary cell; hind-wings 1–1¼, trapezoidal-ovate, cilia ⅛–⅙ ; 3–5 [CuA_1-M_2] remote and tolerably parallel, 6 and 7 [M_1 and RS] stalked or seldom 6 [M_1] absent (coincident), 8 [Sc+R_1] connected with cell in middle'.

He concludes: 'notwithstanding the variability of accessory characters, the constant structure of the palpi and neuration is so marked and distinct that no genus is easier of recognition.' These characters were regarded as of primary importance in confirming the generic placement of *I. vitiensis* **sp. n.**

***Imma vitiensis* sp. n.**

(Figs 4–8)

Material examined. Holotype ♂, FIJI, Viti Levu, Tubarua, Serua province [-18°11'55" 178°00'20"], 12.iv.97, at light, J. Clayton. Genitalia slide G642.
Paratypes: 1 ♂ data as holotype. 1 ♂ FIJI, Viti Levu Monasavu, Naitasiri province [-17°43'28" 178°01'55"], 5.iv.05, at light, J. Clayton. Genitalia slide G639.

Diagnosis. Male *Imma vitiensis* **sp. n.** can readily be separated from other Fijian *Imma* species by its colouration and wing pattern. The forewings are dominated by areas with dark striations on a pale background, which are not found in any other known Fijian species. *Imma vitiensis* **sp. n.** is closest to a pale example of *I. autodoxa*, but there are also clear differences in the male genitalia. It can be distinguished by the two projections which terminate the juxta which are broad and rectangular in shape, whereas in *I. autodoxa* they are narrow, and the uncus which tapers throughout, whereas in *I. autodoxa* it is broad then tapers abruptly to a point. Also in the aedeagus *I. autodoxa* lacks the two bundles of fibres noted above for *I. vitiensis* **sp. n.**

Description. Male (Figs 4, 5). Head: whitish buff with small scattered brown markings, densely clothed in coarse hair-scales, between eyes arranged to form a raised crest and elsewhere loosely appressed; ocelli absent; chaetosemata present; antennae buff, bifasciculate, approximately half length of forewing; scape large with loosely appressed scales similar to head, without pecten; labial palpi curved, ascending with segments in approximate ratio 1:2:1, whitish buff; segments 1 and 2 densely clothed with loosely appressed hair scales; upper half of basal segment brown; second segment brown laterally; terminal segment with diffuse brownish band centrally and smaller, tightly appressed scales making it appear much narrower; maxillary palpi obsolete. Thorax: whitish-buff with narrow

Figs 1–5. *Imma* spp.: (1) *I. leucomystis* Meyrick male; (2) *I. philonoma* Meyrick male; (3) *I. autodoxa* Meyrick male; *I. vitiensis* **sp. n.** male: (4) paratype, (5) holotype.

band of diffuse brown colouration anteriorly. Wingspan 18–22 mm. Forewings: sub-rectangular, twice as long as broad; costa bowed at extreme base, and more gradually towards apex; apex obtuse; termen convex; venation illustrated in Fig. 8; pale buff with brown markings; small transverse strigulations scattered more or less over whole of wing; basal one sixth of wing with fewer strigulations, and with a small, dark sub-basal spot; on costa between one fifth and two fifths, a darker, sub-quadrate area extending half way across wing; a similar but more ovate area in dorsal half of wing from one half, and stopping short of dorsum itself; these two darker areas joined to form a broad irregular fascia, extended to tornus with a narrower dark band; this extension sometimes obsolete; reniform stigma consisting of a small circular dark mark; area near apex pale with only a few weak strigulations; dark terminal fascia and cilia. Hindwings: venation illustrated in Fig. 8; whitish buff, somewhat paler than forewings; brownish terminal shade, darker and extending half-way across wing in region of disc. Legs: whitish buff; fore and hind tibiae with two spurs medially, and hind tibiae with two larger spurs terminally in addition; tibiae clothed with long, dense, loosely appressed hair

scales; femora and tarsi clothed with smaller scales tightly appressed; all tibiae with darker areas adjacent to the bases of the spurs. Abdomen: uniform whitish-buff.

Male genitalia (Fig. 6): Valva gradually tapering from one quarter of length to one sixth, apex with fairly small cucullus with rounded vertices and narrow pointed process at its base; juxta terminated by two broad rectangular shaped projections; uncus pointed and tapering throughout; aedeagus (Fig. 7) eight times as long as broad, curved and with bulbous expansion at base; two internal structures each consisting of a large number of fibrous elements grouped into a bundle and just less than one third of the length of the aedeagus, with the two bundles running parallel and close together.

Variation. Figs 4 and 5 depict wing colour-pattern.

Female. Unknown.

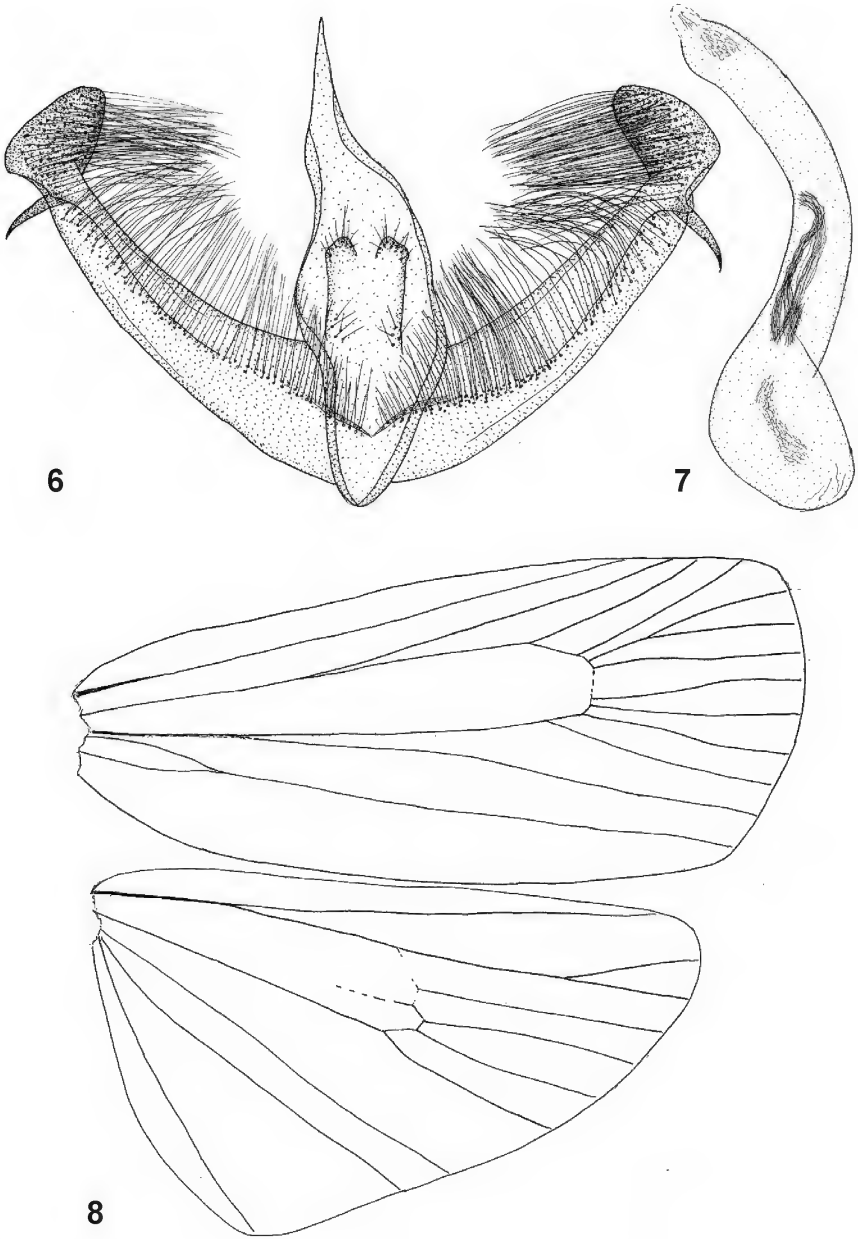
Etymology. The name *vitiensis* (Latinised adjective) refers to the occurrence of the species in Fiji.

Discussion

Species of Immidae can be superficially very similar to Copromorphidae and many species of Tortricidae. Robinson *et al*. (1994) recognised this and provide simple differentiating features. Copromorphidae lack chaetosemata and have numerous tufts of raised scales on the forewing. *Imma vitiensis* **sp. n.** exhibits chaetosemata, and has no such scale tufts. In Immidae, the forewing vein CuA2 arises distally, very near the end of the cell, whereas in Tortricidae it arises more proximally. These features help to support the placement in Immidae, but this is confirmed in detail by placement in the genus *Imma*, as follows.

Imma vitiensis **sp. n.** shows all the features of Meyrick's (1906) elaboration of Walker's (1859) original generic definition, quoted in the introduction to the genus *Imma* above. The head of *I. vitiensis* **sp. n.** agrees with his description; specifically 'with loosely appressed hairs, sometimes .... erect on crown', the labial palpi 'moderately long, curved, ascending', 'second joint thickened with dense scales' and 'terminal joint seldom more than half second, pointed or obtuse'. The wing venation (Fig. 8) also agrees; in the forewing 1A+2A is furcate; CuA_2 arises near angle of cell; R_4 and R_5 stalked; R_4 and R_5 to termen; R_1 to R_3 roughly equidistant; no secondary cell; in the hindwing CuA_1 to M_2 roughly parallel; M_1 and RS stalked; $Sc+R_1$ from approximately middle of cell. These features all agree with Meyrick's definition. There is a good match for the form of the palpi and the wing venation which he singles out as key features which make the genus easy of recognition.

The wing venation also shows a close similarity to that of *I. mackwoodi* Moore illustrated by Robinson *et al.* (1994).



Figs 6–8. *Imma vitiensis* **sp. n.**: (6) male genitalia; (7) aedeagus; (8) wing venation.

Acknowledgements

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PALAEOSYNTHEMIS PAPILIO SP. N., A NEW DRAGONFLY FROM PAPUA NEW GUINEA (ODONATA: ANISOPTERA: SYNTHEMISTIDAE)

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Abstract

Palaeosynthemis papilio **sp. n.** is described from a single male collected in the Purari River basin in the Gulf Province of south-central Papua New Guinea. The male is most similar to *P. elegans* Theischinger and Richards, 2013, a species currently known only from the Sepik River basin on the northern side of New Guinea's central cordillera, but can be distinguished from that species and all other congeners by the lack of yellow markings on the face, the presence of a pale antehumeral patch and a butterfly-like yellow medio-dorsal patch on abdominal segment 3, and absence of a spine on the dorsum of abdominal segment 10. The new species flies predominantly at dusk, in clearings in lowland tropical rainforest.

Key words: *Palaeosynthemis,* taxonomy, new species, Purari River basin

Introduction

The synthemistid genus *Palaeosynthemis* Förster, 1903 is a group of slender, predominantly crepuscular dragonflies that is endemic to the New Guinean region (Orr and Kalkman, 2015). Eleven species occur on mainland New Guinea at altitudes between sea level and nearly 2,000 m a.s.l., and one species is endemic to Halmahera Island in the Maluku Islands west of New Guinea (Orr and Kalkman, 2015). Taxonomic research on *Palaeosynthemis* (formerly included within *Synthemis* Selys, 1870) has been sporadic (Förster, 1903; Campion, 1915; Lieftinck, 1935, 1938), and following Lieftinck's (1953) major revision of the genus, 60 years elapsed before it was revisited (Theischinger and Richards, 2013, 2014, 2016). Here we describe a new species of *Palaeosynthemis* from the lowlands of Gulf Province in south-central Papua New Guinea. Its description brings to 13 the number of named *Palaeosynthemis* species, 12 of which are endemic to the New Guinea mainland.

Material and Methods

Descriptive terminology largely follows Chao (1953) and Watson and O'Farrell (1991). Coloration was assessed from the preserved holotype, supplemented with photographs taken of the same specimen in life. Measurements are given in millimetres (mm). All illustrations were done with the aid of a camera lucida and are not to scale. Coordinates presented are based on the GPS datum WGS 84. Abbreviations used are: SAMA for South Australian Museum, Adelaide, Australia; Ax for antenodal crossvein; Fw for forewing; Hw for hind wing and S for abdominal segment(s).

***Palaeosynthemis papilio* sp. n.**

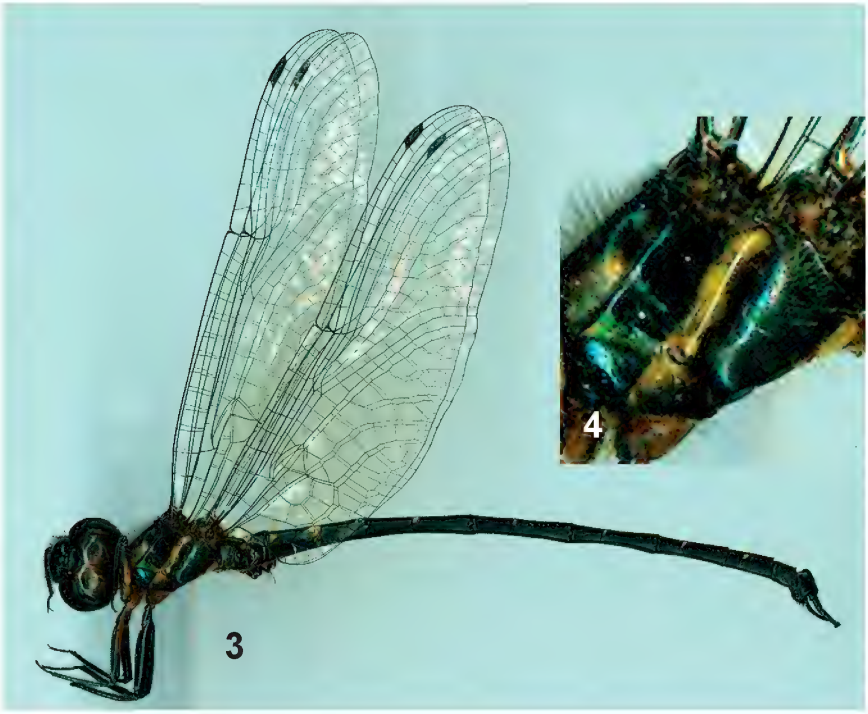
Figs 1, 3–9

Material examined. Holotype ♂ PAPUA NEW GUINEA: Gulf Province, Purari River basin (7.146°S, 145.141°E; 100 m a.s.l.), 25.i.2016, S.J. Richards, in SAMA collection (SAMA 07-001578).

Diagnosis. A medium-sized black dragonfly that can be distinguished from males of all congeners by the following combination of characters: lack of yellow markings on the face; presence of a pale antehumeral patch, and a butterfly-shaped yellow medio-dorsal patch on abdominal segment 3; lack of antero-dorsal spots on abdominal segment 4 and of a spine on the dorsum of abdominal segment 10; and superior anal appendages latero-ventrally thickened for the basal ca. 20% and bent medially for the apical ca. 10%.

Description of holotype. Head: labium and mandibles yellowish grey to brownish black; labrum largely black; anteclypeus greyish yellow; postclypeus and genae black; anterior frons greyish brown; top of head including top of frons, vertex, occiput and antennae black; postgenae black. Eyes green in life, dark brown in the preserved specimen. Thorax: prothorax largely black; pronotum black with only rim of anterior lobe and median portion of rim of posterior lobe yellow. Coxa and trochanter yellowish grey to greyish brown, leg otherwise largely black with much of outer face of femur brownish to greyish yellow. Synthorax with mid-dorsal carina yellowish brown to greyish brown, dorsal edge bright yellow; antealar sinus all black. Pleura black with metallic reflections; patch in ventro-lateral portion of mesanepisternum, stripe along intersegmental suture covering metastigma, and postero-ventral corner of metepimeron plus metapostepimeron bright to dark yellow. Terga largely brownish black, postnota yellow. Poststernum yellowish grey with patch of blackish brown each side, postcoxae yellowish grey. Coxae yellowish brown to greyish brown, remainder of legs largely black, much of inner face of midfemur brownish to greyish yellow. Wings with venation black and membrane hyaline; intermediary pieces bright yellow; Ax1 and Ax3 thickened in Fw, every second Ax thickened in Hw; antenodals 12/8, postnodals 6/8–10; medial crossveins 1/1; cubital crossveins 4/3; triangles and subtriangles free of crossveins; supertriangles with one crossvein; discoidal field of forewing beginning with 1 row of cells for 6 cells, discoidal field of hindwing beginning with 1 row of cells for 4 cells; anal loop containing 5 cells, no central cell; anal triangle with one crossvein; membranule pale grey, at least 3/4 as long as anal triangle; pterostigma black, 3–4 times as long as wide, slightly longer in forewing than in hindwing, overlying one cell (2 veins) and parts of a cell at each end. Abdomen: S1 dorsally black. S2–10 black, marked with light yellow as follows: S2 with wing-like patch each side on transverse carina; S3 with subtriangular antero-dorsal spot each side, rather widely separated along midline, and two large medio-dorsal spots, each constricted centro-laterally, very close together, almost touching along midline, creating a butterfly-like image (Figs 1, 6, 7); S4 with subtriangular spots on each side, narrowly separated, each with short anterior extension; S5–7 with almond-shaped, medio-dorsal spot each side on/posterior

Figs 1, 2. *Palaeosynthemis* spp., male, in life: (1) *P. papilio* **sp. n.;** (2) *P. elegans*. Photographs by Stephen Richards. Fig. 2 modified from Theischinger and Richards (2013).



Figs 3, 4. *Palaeosynthemis papilio* **sp. n.,** male: (3) habitus, lateral; (4) synthorax, lateral.

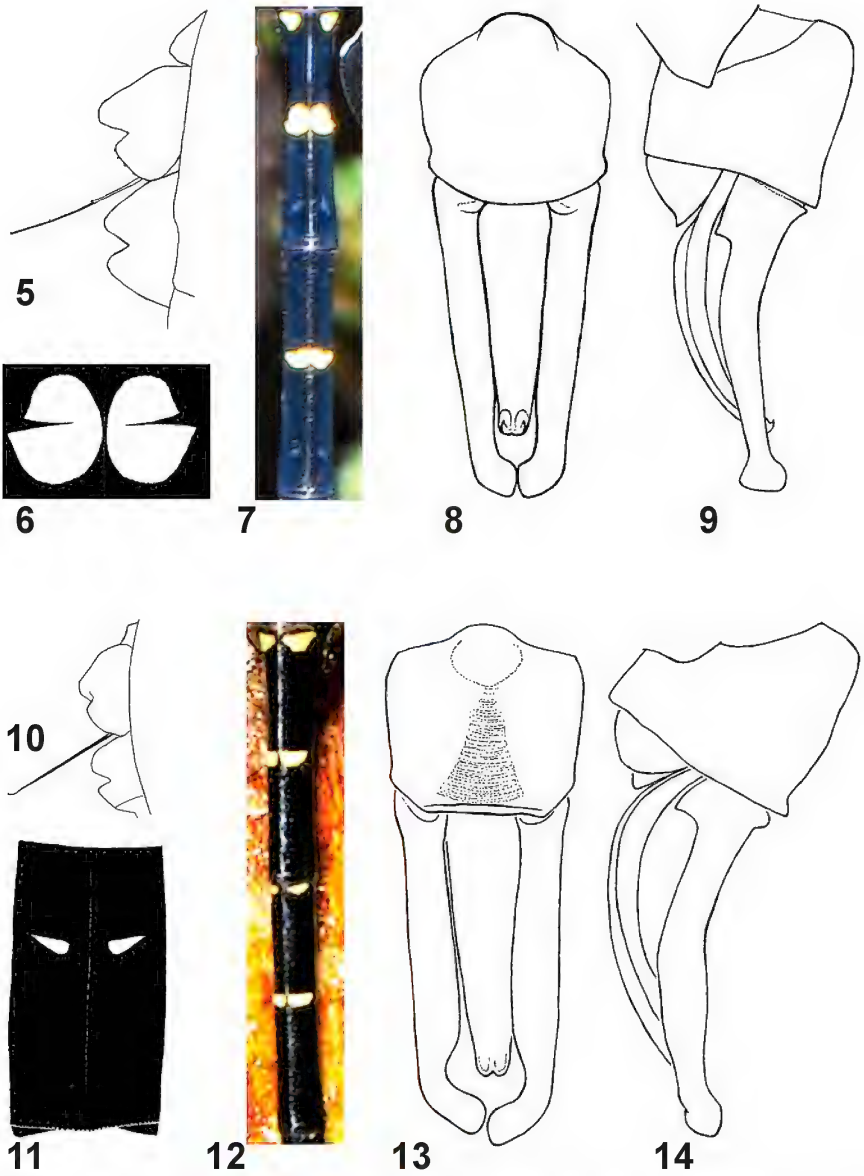
to transverse carina, these only narrowly separated; S8 similar to S4–7 but mid-dorsal separation slightly wider; anal appendages black. Secondary genitalia as illustrated (Fig. 5). Superior anal appendages slightly less than 2X length of S10, slender, with basal ca. 20% latero-ventrally distinctly thickened, next ca. 70% slightly curved dorsally and narrowing with apical ca. 10% thickened and bent medially with indistinct subapical mesal excavation; inferior appendix about ¾ as long as superiors, widely and evenly curved dorsally, apically slightly bilobed and hooked.

Measurements: forewing 31.2 mm; hindwing 30.0 mm; abdomen + appendages 38.5 mm.

Etymology. The specific name (papilio = Latin for butterfly) refers to the prominent composite medio-dorsal yellow mark on S4 of the male that resembles a butterfly.

Habitat and distribution

The holotype of *Palaeosynthemis papilio* **sp. n.** was found sleeping on a thin branch approximately 1.8 m above the ground at night (Fig. 1) in wet lowland rainforest adjacent to a small, clear-flowing stream (Fig. 15). Although only one *P. papilio* **sp. n.** was captured, several other individuals tentatively assigned to



Figs 5–14. *Palaeosynthemis* spp., male: (5–9) *P. papilio* **sp. n.:** (5) secondary genitalia, lateral; (6) butterfly-mark on S3; (7) S3 and S4, dorsal; (8, 9) anal appendages: (8) dorsal; (9) lateral; (10–14) *P. elegans*: (10) secondary genitalia, lateral; (11) S8, dorsal; (12) S3 and S4, dorsal; (13, 14) anal appendages: (13) dorsal; (14) lateral. Figs 10, 11, 13, 14 modified from Theischinger and Richards (2013).

this species were observed hawking in forest clearings at the type locality at dusk. *Palaeosynthemis papilio* **sp. n.** is currently known only from one location in the Gulf Province lowlands of south-central Papua New Guinea but, given the vast extent of suitable habitat, and lack of major regional biogeographic barriers in the southern lowland rainforests, it probably has a broad distribution in southern Papua New Guinea.

Remarks

The description of *P. papilio* **sp. n.** brings to 12 the number of *Palaeosynthemis* species known from mainland New Guinea. These species can be placed into two broad groups, those having yellow markings on the face and those lacking any yellow on the face. *Palaeosynthemis papilio* **sp. n.** falls into the latter group, and so can be easily distinguished from *P. cervula* (Lieftinck, 1938), *P. feronia* (Lieftinck, 1938), *P. opaca* Theischinger and Richards, 2016 and *P. primigenia* (Förster, 1903) which all have distinct yellow markings on the face. Of the species with all-dark faces, the male of *P. papilio* **sp. n.** is distinguished from *P. cyrene* (Lieftinck, 1953), *P. nigrostigma* Theischinger and Richards, 2014, and from an undescribed species labelled as *P.* sp. B by Orr and Kalkman (2015) in lacking (vs having) a spine on the dorsum of S10, and from *P. gracilenta* (Lieftinck, 1935) and *P. kimminsi* (Lieftinck, 1953) by having (vs lacking) pale antehumeral marks. Two additional species with dark faces, *P. evelynae* (Lieftinck, 1953) and *P. wollastoni* (Campion, 1915) are known from limited material, making comparisons difficult. *Palaeosynthemis evelynae* is known only from one female and one incomplete male, collected at an altitude of 1,200 m a.s.l. in the Owen Stanley Mountains of eastern Papua New Guinea. It appears to be a larger species (Hw of the male 35.5 mm vs 30.0 mm in *P. papilio* **sp. n.**) and has a different pattern of yellow spots on the abdomen, including those on S2 consisting of a pair of oval yellow-orange spots (vs a pair of narrow, elongate wing-shaped markings in *P. papilio* **sp. n.**), and those on S3–5 consisting of 'similar small spots' medially and S3–4 with additional latero-basal spots (Lieftinck, 1953) (vs medial spots on S3 large, forming distinct butterfly shape, and S4 without antero-lateral spots, in *P. papilio* **sp. n.**). *Palaeosynthemis wollastoni* is known only from a single female, collected at an altitude of 1,200–1,800 m a.s.l. (Orr and Kalkman, 2015) in western New Guinea (Campion, 1915). It also appears to be a larger species than *P. papilio* **sp. n.** (Hw 42 mm, abdomen + ovipositor 48.5 mm vs. Hw 30.0, abdomen + appendages 38.5 mm), though it is not possible to discount the effects of sexual size dimorphism on these differences. However, *P. wollastoni* also differs from the new species in having the subtriangle of the hindwing traversed by a single crossvein (vs. subtriangle free in *P. papilio* **sp. n.**). The substantially different altitudes of their collection (100 m a.s.l. in lowland rainforest for *P. papilio* **sp. n.**, vs. 1,200 m a.s.l. and 1,200–1,800 m a.s.l. in the mountains for *P. evelynae*, and *P. wollastoni* respectively) also indicate possible different ecologies for these species. The species most closely resembling *P. papilio* **sp. n.** (Figs 1, 5–9) is *P. elegans* Theischinger and Richards, 2013 (Figs 2, 10–14), a species with pale antehumeral marks but without yellow markings on the face and without a spine

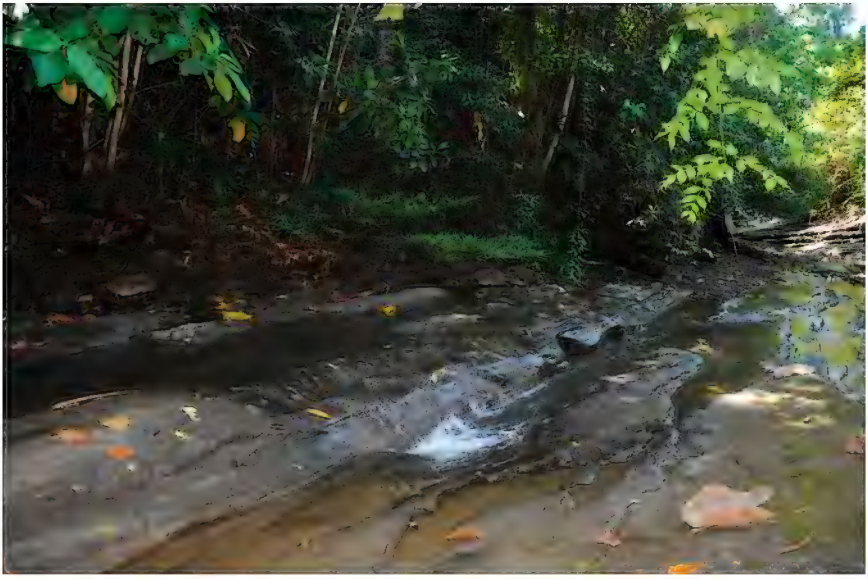


Fig. 15. Habitat of *Palaeosynthemis papilio* **sp. n.** in the Purari River basin, Papua New Guinea.

on the dorsum of S10 in the male. Marked differences between these two species in the secondary genitalia (Fig. 5 vs Fig. 10) were not detected. The general shape of the anal appendages is also similar, but the superior anal appendages of male *P. papilio* **sp. n.** are latero-ventrally thickened for the basal ca. 20% (Fig. 9) and bent medially for the apical ca. 10% distal to a barely detectable subapical mesal excavation (Fig. 8) (vs. latero-ventrally thickened for the basal ca. 10% (Fig. 14) and bent medially for the apical ca. 20% distal to a distinct subapical mesal excavation (Fig. 13) in *P. elegans*). Furthermore the pattern of yellow markings on the abdomen differs markedly: in *P. papilio* **sp. n.** there is a pair of yellow antero-dorsal marks and a prominent yellow butterfly-like medio-dorsal patch on S3 and a single, yellow medio-dorsal patch on S4 (Figs 1, 7), whereas in *P. elegans* there are a pair of yellow antero-dorsal and a pair of yellow medio-dorsal marks on both S3 and S4 (Figs 2, 12), and the yellow medio-dorsal spots on S8 are larger than the area that separates them in *P. papilio* **sp. n.** (Fig. 1), but smaller in *P. elegans* (Figs 2, 11).

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PROTECTED TAXONOMIC STATUS FOR *PAPILIO HARPALYCE* DONOVAN, 1805 (LEPIDOPTERA: PIERIDAE), A JUNIOR PRIMARY HOMONYM OF *PAPILIO HARPALYCE* CRAMER, 1777 (LEPIDOPTERA: NYMPHALIDAE)

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Abstract

Papilio harpalyce Donovan, 1805 from Australia is a junior primary homonym of *Papilio harpalyce* Cramer, 1777 from Africa and, under most circumstances, cannot be used to designate the pierid butterfly currently known as *Delias harpalyce* (Donovan, 1805). The oldest available name for the Australian species is *Papilio lewini* Thon, 1827. Under Article 23.9.2 of the Fourth Edition of the *International Code of Zoological Nomenclature*, however, we regard the name *Papilio harpalyce* Donovan, 1805 as valid and qualified as a *nomen protectum* and declare the name *Papilio lewini* Thon, 1827 as invalid and qualified as a *nomen oblitum*.

Donovan (1805) proposed the name *Papilio harpalyce* for a pierid butterfly from Australia, which is currently known as *Delias harpalyce* (Donovan, 1805) (Edwards 1996, Edwards *et al.* 2001, Braby 2010). Edwards *et al.* (2001) indicated that the syntypes of *Papilio harpalyce* Donovan, 1805 are missing, but concluded that the type locality is Sydney. *Delias harpalyce* is a large, striking species endemic to south-eastern Australia, and is well-known to entomologists and butterfly collectors in Australia, often by its common name the Imperial Jezebel or Imperial White (Braby 2004, 2016), as well as to collectors overseas with an interest in the large and speciose genus *Delias* Hübner, [1819] (e.g. Yagishita *et al.* 1993). However, some 28 years earlier, Cramer (1777) described *Papilio harpalyce* for a nymphalid butterfly from Africa, a species currently known as *Euphaedra harpalyce* (Cramer, 1777) (D'Abrera 1980, Ackery *et al.* 1995, Larsen 2005, Williams 2020). The vernacular or common name for this species is the Common Blue-Banded Forester. Thus, *Papilio harpalyce* Donovan, 1805 and *Papilio harpalyce* Cramer, 1777 are primary homonyms according to Articles 52 and 53 of the International Code of Zoological Nomenclature (ICZN 1999). When two or more taxa are distinguished from each other they must not be denoted by the same name (Article 52.1), and two or more available species-group names having the same spelling are primary homonyms if they were originally established in combination with the same generic name (Article 53.3). Under the Principle of Homonymy, when two or more names are homonyms, only the senior, as determined by the Principle of Priority, may be used as a valid name. In this case, the earliest available name, *Papilio harpalyce* Cramer, 1777, becomes the senior primary homonym and hence the valid name, and the subsequent name *Papilio harpalyce* Donovan, 1805 becomes the junior primary homonym and therefore is invalid.

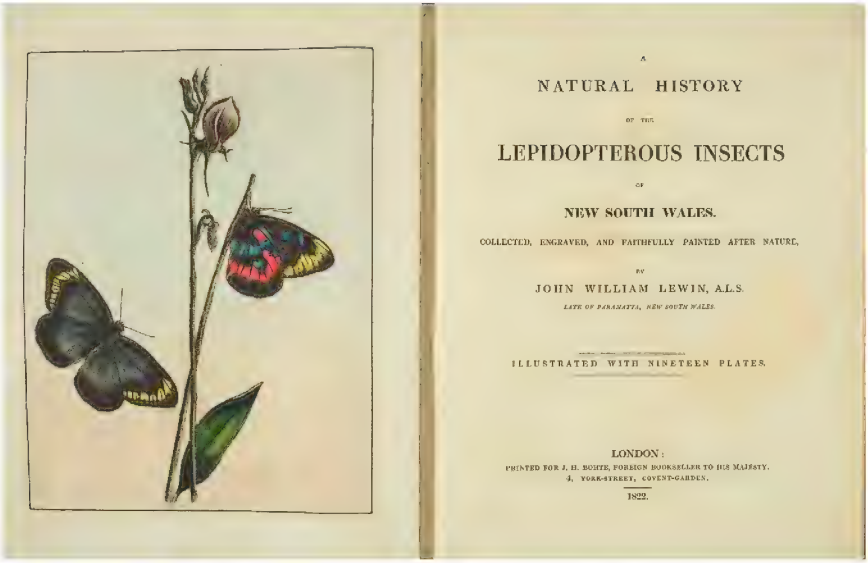

Fig. 1. Syntype(s) of *Papilio lewini* Thon, 1827 illustrated in the frontispiece of Lewin (1822)..

It is rather surprising that, for 215 years, nobody seems to have noticed the homonymy before. The normal course of action would be that *Papilio harpalyce* Donovan, 1805 cannot be used to designate the Australian species. There is, however, a second name, *Papilio lewini* Thon, 1827, which technically is the oldest available name for the Australian species and thus the senior synonym. Thon's (1827) published name, description and illustration (on page 38, fig. 10) are curious. Lewin's brother Thomas added a coloured frontispiece to the second edition of John William Lewin's work on New South Wales Lepidoptera (Lewin 1822), which illustrates two females of Donovan's butterfly (Fig. 1), but no text or explanation were provided for the frontispiece. Thon gave the name *Papilio lewini* to the frontispiece of Lewin's (1822) second edition (Moulds 1977, Edwards *et al.* 2001), apparently unaware that Donovan had introduced the name *P. harpalyce* 22 years earlier. Thus, the syntype(s) for *Papilio lewini* are the female(s) specimen(s) illustrated by Lewin, and the type locality is New South Wales (Edwards *et al.* 2001). Because the syntype(s) are no longer in existence, or if they do remain none have been positively identified (E.D. Edwards, pers. comm.), it is not known if Lewin illustrated two specimens, one showing the upperside and the other depicting the underside, or prepared two illustrations of a single specimen. Since the syntype(s) of *Papilio lewini* must have been collected and painted well before 1820 (i.e., before Lewin's death in Sydney on 27 August 1819), it is reasonable to assume that they came from a limited area around Sydney where Lewin undertook most of his collecting and rearing or possibly the Hunter River (Braby and Olsen 2011, Neville 2012).

Table 1. Evidence that the junior primary homonym *Papilio harpalyce* Donovan, 1805 has been used to denote the taxon currently known as *Delias harpalyce* (Donovan, 1805) in at least 25 works, published by at least 10 authors during the last 50 years (1971–2020) and encompassing a span of not less than 10 years, and thus fulfilling the conditions of Article 23.9.1.2 of the Code in order to reverse the precedence of the senior synonym *Papilio lewini* Thon, 1827.

Reference
1. D'Abrera (1971, p. 146): *Delias harpalyce* Donovan
2. McCubbin (1971, p. 121): *Delias harpalyce* (Donovan) 1805
3. Common and Waterhouse (1972, p. 210): *Delias harpalyce* (Donovan), 1805
4. De Baar (1985, p. 90): *Delias harpalyce*
5. Braby (1987, p. 187): *Delias harpalyce* (Donovan)
6. Douglas and Braby (1989, p. 65): *Delias harpalyce* (Don.)
7. Dunn and Dunn (1991, p. 50): *Delias harpalyce* (Donovan), 1805
8. New (1991, p. 135): *Delias harpalyce* (Donovan)
9. Braby and Douglas (1992, p. 9): *Delias harpalyce* (Donovan)
10. Coupar and Coupar (1992, p. 115): *Delias harpalyce*
11. Faithfull (1992, p. 163): *Delias harpalyce* (Donovan)
12. Braby (1993, p. 25): *Delias harpalyce* (Donovan)
13. Smithers (1993, p. 28): *Delias harpalyce* (Donovan)
14. Yagishita *et al.* (1993, p. 286): *Delias harpalyce* Donovan, 1805
15. Fisher (1995, p. 104): *Delias harpalyce*
16. Tuzov (1996, p. 119): *Delias harpalyce* Donovan, 1805
17. Braby (2000, p. 334): *Delias harpalyce* (Donovan, 1805)
18. Braby and Lyonns (2003, p. 138): *Delias harpalyce* Donovan
19. Braby (2004, p. 136): *Delias harpalyce*
20. Braby (2005, p. 161): *Delias harpalyce* (Donovan)
21. Braby and Pierce (2007, p. 2): *Delias harpalyce* (Donovan)
22. Braby and Nishida (2010, p. 1899): *Delias harpalyce* (Donovan, 1805)
23. Orr and Kitching (2010, p. 156): *Delias harpalyce*
24. Field (2013, p. 142): *Delias harpalyce* (Donovan, 1805)
25. Bond (2016, p. 96): *Delias harpalyce*
26. Wee and Monteiro (2017, p. 3/20): *Delias harpalyce*
27. Haywood (2019, p. 89): *Delias harpalyce* (Donovan, 1805)
28. Sankowsky (2020, p. 89): *Delias harpalyce*

The African species *Papilio harpalyce* Cramer, 1777, which is currently placed in the genus *Euphaedra* Hübner, [1819], is restricted to western and central Africa. Ackery *et al.* (1995) and Williams (2020) provide a useful species-group synonymy in which seven taxa are treated as valid subspecies, including the synonymy of *Romaleosoma spatiosa* Mabille, 1876, as follows:

Euphaedra harpalyce (Cramer, 1777) (*Papilio*)
lakuma (Butler, 1870) (*Romaleosoma*) [junior synonym]
spatiosa (Mabille, 1876) (*Romaleosoma*) [subspecies of *harpalyce*]
serena Talbot, 1928 (*Euphaedra*) [subspecies of *harpalyce*]
sudanensis Talbot, 1929 (*Euphaedra*) [subspecies of *harpalyce*]
dowsetti Hecq, 1990 (*Euphaedra*) [subspecies of *harpalyce*]
vana Hecq, 1991 (*Euphaedra*) [subspecies of *harpalyce*]
evanescens Hecq, 1995 (*Euphaedra*) [subspecies of *harpalyce*]
comminuera Hecq, 1999 (*Euphaedra*) [subspecies of *harpalyce*]

Article 23.9.5 of the International Code of Zoological Nomenclature (ICZN 1999) states that "When an author discovers that a species-group name in use is a junior primary homonym [Art. 53.3] of another species-group name also in use, but the names apply to taxa not considered congeneric after 1899, the author must not automatically replace the junior homonym; the case should be referred to the Commission for a ruling under the plenary power and meanwhile prevailing usage of both names is to be maintained [Art. 82]." However, the Code also allows a *nomen protectum* status for *Papilio harpalyce* Donovan (i.e., the junior primary homonym) under its Reversal of Precedence procedure (Article 23.9) provided that certain conditions are met. Two such conditions are: (1) the senior synonym or homonym has not been used as a valid name after 1899 (Article 23.9.1.1), and (2) the junior synonym or homonym has been used in at least 25 works, published by at least 10 authors in the immediately preceding 50 years and encompassing a span of not less than 10 years (Article 23.9.1.2). Thus, according to Article 23.9.1 of the Code, the prevailing usage must be maintained when the senior synonym (i.e., the oldest available name, *Papilio lewini* Thon, 1827) satisfies Article 23.9.1.1, and the junior homonym (i.e., the invalid junior primary homonym, *Papilio harpalyce* Donovan, 1805) satisfies Article 23.9.1.2.

In our opinion, conditions of both articles are met. Whereas we find no evidence that *Papilio lewini* Thon, 1827 has been used as a valid name since 1900, there is substantial evidence that *Papilio harpalyce* Donovan, 1805 has been used as a valid name by more than 25 works of more than 10 authors since 1971 (Table 1). Although both Yagishita *et al.* (1993, p. 286, pl. 144) and Tuzov (1996) recognised the name *lewini*, they incorrectly treated it as a form of *Delias harpalyce*, that is, as "*Delias harpalyce* f. *lewini* Thon, 1828". Moreover, under Article 15.2 of the Code, infrasubspecific names such as "form" or "variety" published after 1960 are excluded from its provisions and thus are not recognised. Therefore, under Article 23.9.2 we regard the name *Papilio harpalyce* Donovan, 1805 as valid and qualified as a *nomen protectum* and declare the name *Papilio lewini* Thon, 1827 as invalid and qualified as a *nomen oblitum*. Since our intention is not to replace

the junior primary homonym, but to qualify *P. harpalyce* Donovan, 1805 as a *nomen protectum* under Article 23.9.2, the action of Article 23.9.5 is avoided, and prevailing usage is thus maintained.

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A NEW SPECIES, *AUSCALA FLAMMEA* (HEMIPTERA: CICADIDAE) FROM SOUTH AUSTRALIA AND SOUTHERN WESTERN AUSTRALIA

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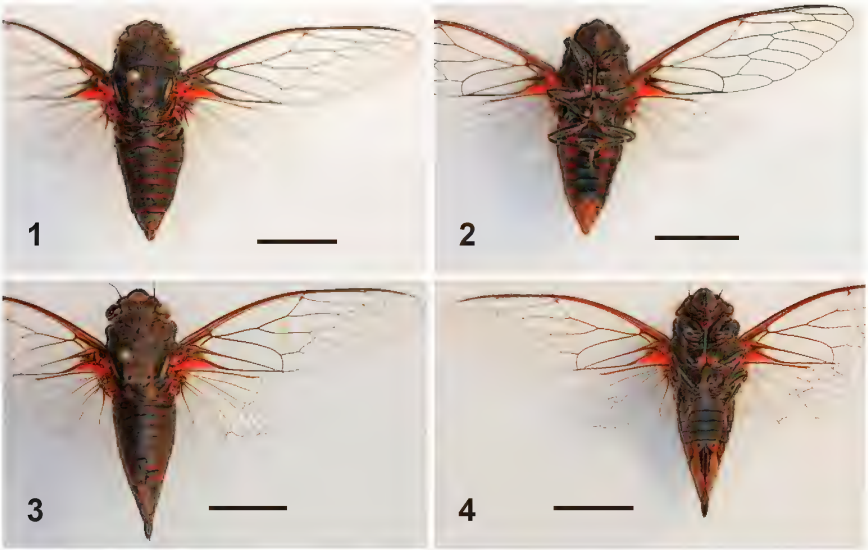
Abstract
A new cicada species, *Auscala flammea* **sp. n.** is described from southern Western Australia and central southern South Australia, as well as an analysis of its calling song and a comparison with the song of *A. spinosa* (Goding and Froggatt, 1904).

Key words: Cicada, *Auscala flammea*, *A. spinosa*, Homoptera, taxonomy, new species

Introduction
The Australian cicada genus, *Auscala* Moulds, 2012 contains a single species, *Auscala spinosa* (Goding and Froggatt, 1904), formerly *Melampsalta spinosa*. The species distribution was recorded as inland southern Queensland, New South Wales (NSW) and Victoria to the South Australian border (SA; Moulds 2012). Goding and Froggatt (1904) had previously described a female from "New Holland" in the South Australian Museum (SAM) and was assumed to originate from that state. This specimen in SAM clearly did not match the original description of *A. spinosa*, but Goding and Froggatt added that they "*examined a male...which agrees with the description of the female*" (location unspecified), raising confusion over the taxonomic status of the various specimens. This was also complicated by definitive reports of *A. spinosa* in south-eastern South Australia around Bordertown (36°13'S 140°47'E) south to Frances (Haywood 2005; 2006). Moulds (1990) clarified this dilemma by designating a lectotype (female) and paralectotype (male) of *A. spinosa*, both currently held in the Australian National Insect Collection (ANIC). Both these specimens have been viewed by one of the authors (DE). With this resolved, it was clear that specimens of *Auscala* from areas of central-western South Australia and southern Western Australia differed from *A. spinosa*, including the original female in SAM.

This report describes a new species *A. flammea* **sp. n.** from southern Western Australia and central southern South Australia. We also present the song descriptions of both *Auscala* species, expanding on the original song description of *A. spinosa* by Haywood (2005; 2006).

Materials and Methods
Anatomical terminology follows Moulds (2005, 2012) for body structures and wing characters, Moulds (2005) for genitalia, and Dugdale (1972) and Bennet-



Figs 1–4. *Auscala flammea* **sp. n.** (1, 2) holotype male (1) dorsal habitus; (2) ventral habitus. (3, 4) paratype female; (3) dorsal habitus; (4) ventral habitus. Specimens from Dryandra State Forest, WA, 32°46'48"S 116°52'48"E. Scale bar = 10 mm.

Clark (1997) for timbals. The long timbal ribs are referred to as long ribs 1 to 5, with long rib 1 being the most posterior (adjacent to timbal plate). The higher classification adopted in this paper for *Auscala* follows Moulds (2012). Measurements (in mm) are given as ranges and means (in parentheses) and include the largest and smallest specimens. Head width spans across the eyes; pronotum width across the extremities of the lateral margins; abdomen width is measured across the outer edges of the auditory capsules. Specimens were examined and photographed with an Olympus SZ61 stereo microscope and Cell-sens ™ software.

Male genitalia were removed using a pair of surgical scissors and placed in a solution of 10% potassium hydroxide. The solution was left overnight at room temperature to clear the soft tissues and provide a clean dissection. Following clearing, the specimens were washed with ethanol and placed into a solution of either 70% ethanol or glycerol. The aedeagus was flexed posteriorly and examined under 10x magnification. Measurements were taken using a pair of Supatool ™ digital calipers (DE), or an electronic digital caliper (PH), both accurate to 0.01 mm.

Calling song analysis: Song terminology follows Popple (2013) and is similar to Emery *et al.* (2019). A 'syllable' refers to the shortest duration unit of sound produced. A grouping of repeated syllables with measurable silent gaps between each syllable is referred to as a 'syllable sequence'. A coalesced and/or adjoining group of syllables is referred to as an 'echeme'. When the song contains multiple

echemes or combinations of echemes and syllables that form a repetitive structure, the term 'phrase' is used to describe each repeated unit. Calling song analysis was performed using Cool Edit Pro (2.0) software. Two elements of calling song frequency (pitch) were examined: (1) dominant frequency, and (2) high amplitude plateau. The former was measured as the highest single amplitude reading on a Fast Fourier Transform (FFT) spectrum, over a 50–100 ms clip of high-quality recording (1024 FFT size, Blackman Harris representation with a linear frequency axis). The latter was measured by analysing the highest amplitude over the same FFT sample. Recordings were checked for potential background interference before running the analysis.

Abbreviations are used in the text as follows: WAM– Western Australian Museum, Perth; SAM– South Australian Museum, Adelaide; DE– Private collection of D. Emery, Sydney; PMH– private collection of P. Hutchinson, Perth; MSM– private collection of M.S. Moulds, Kuranda; LWP– private collection of L.W. Popple, Cairns.

Systematics

Family Cicadidae Latreille, 1802
Subfamily Cicadettinae Buckton, 1889
Tribe Cicadettini Buckton, 1889
Genus *Auscala* Moulds, 2012

Auscala flammea sp. n.

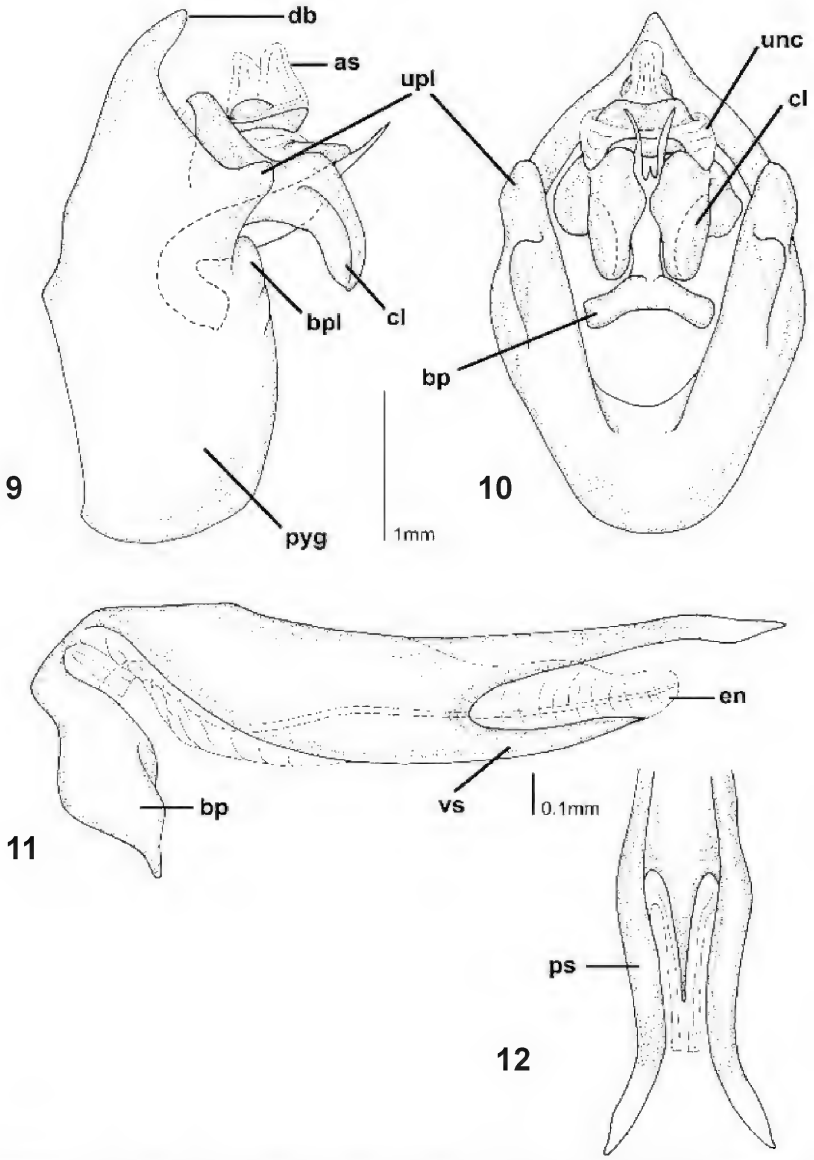
(Figs 1–18)

Type material. Holotype ♂, **WESTERN AUSTRALIA:** Dryandra State Forest, 32°46'48"S 116°52'48"E, 11.xi.2017, P. Hutchinson (to light) (WAM).

Paratypes. **WESTERN AUSTRALIA:** 1♂, Widgimooltha, 21.i.1968, L.E. Koch, A.M. Douglas, WAM Reg. no. 72998; 2♂, 1 mile E Hammersley Inlet to Dempster Inlet, Fitzgerald River Reserve, 5.i.1971, L.E. Koch, W.K. Youngson, WAM Reg. no. 72999-300; 1♂, 1♀, Lake Grace, 51-2108 [8.viii.1951], A.M. Douglas, WA., WAM Reg. nos 73002, 73009; 1♂, Trayning, WA, 10.i.1978, G. Riley, WAM Reg. no. 73005, Barcode of Life DNA voucher specimen sample l [CCDB-27057-EO1 Bold Proc. ID: WAM A619-15]; 1♂, 70–75 km ENE Norseman, WA, 10–16.xi.1978, T.F. Houston et.al. #87/1499, WAM Reg. no. 73007; Barcode of Life DNA voucher specimen sample l[CCDB-27057-D11 Bold Proc. ID WAM A617-15]; 1♀, E[d]judina, WA, 29°48'S 122°21'E, A.M. Douglas, WAM Reg. no. 73001; 1♂, Fitzgerald River Nat. Park W.Aust., 33°59'S 119°15E, 24–28.xii.1978, T.F. Houston 240-7, on stem of tree or shrub, Western Australian Museum Collection 88/1368, WAM Reg. no. 73006, Barcode of Life DNA voucher specimen sample l [CCDB-27057-DIZ Bold Proc: ID WAM A618-15]; 1♂, Buningonia spring (well), 31°26'S 123°33'E, W. Aust., 18–25.xi.1978, T.F. Houston et.al. 225, calling from *Eucalyptus oleosa*, WAM Reg. no. 88/1407 (WAM); 3♂, same data as holotype; 1♂, Brookton Hwy., 50 km SE Kelmscott, WA., 33°13'48"S 116°26'24"E, 20.xii.2016, P. Hutchinson (genitalia prep); 2♀, same data as holotype, 1.i.2017, P. Hutchinson; 1♂, Brookton Hwy, 50 km SE Kelmscott, WA., 33°13'48"S 116°26'24"E, 13.xi.2015, P. Hutchinson (to mv light) (DE); 5♂, 2♀, same data as holotype; 1♂, same location, 1.i.2017, P. Hutchinson (to mv light); 3♂, 3 km ESE Ravensthorpe, 33°35'24"S 116°26'24"E, 8.xii.2003, P. Hutchinson (on *Eucalyptus*); 1♂, 1♀, Brookton Hwy, 50 km SE Kelmscott,

Figs 5–8. *Auscala flammea* **sp. nov.:** (5) photostack of male left timbal, with anterior margin at top and dorsal margin at right; (6) photostack of male left opercula, with anterior margin at top and dorsal margin at right; (7) male abdomen viewed laterally from the left. Specimen from Dryandra State Forest (32°46'48"S 116°52'48"E); (8) Typical habitat in Dryandra State Forest, WA, showing stands of *Eucalyptus wandoo* favoured by this species. Scale bar = 0.2 mm.

WA., 33°13'48"S 116°26'24"E, 15.i.2017, P. Kay (to mv light); 1♂, same location as previous, 9.xii.2016, P. Kay (to mv light); 1♂, 1♀, Walyunga Nat. Pk., N Perth, WA., 31°43'48"S 116°03'36"E, 12.xii.2013, P. Kay (to mv light); 1♂, 22 km SSW Newdegate, WA, 33°14'24"S 118°57'E, 29.xii.2008, T.M.S. Hanlon (active in heath); 1♀, Evanston Road, 34 km N Bullfinch WA, 30°43'48"S 119°13'48"E 14.i.2013. P. Hutchinson (to mv light) (PMH); 2♂, Oldfield River at road crossing E Ravensthorpe, 4.xi. 1978, M.S. & B.J. Moulds; 1♂, Pallingup River x-ing, 30 km W Gnowangerup, 9.xii.1985, M.S. & B.J. Moulds; 1♀, Mingenew, 28.xii.1978, K. & E. Carnaby; 1♀, 160 km E Kalgoorlie, [along] Trans Aust. Railway, 21.i.1991, M.S. & B.J. Moulds;1♂, Beacon, 4.xii.1978, M. Powell; 1♂, Lancelin, 7.i.1979, K. & E. Carnaby; 2♂, WAU.BOX, Pallingup R., at South Coast Hwy, 37°24'S 118°44'E, 9.i.2003, Moulds, Marshall, Hill & Vanderpool; 1♂, WAU.FTZ, Fitzgerald R., 35.7 km E Jerramungup, 33°50'S 119°16'E, 10.i.2003, 231 m, Moulds, Marshall, Hill & Vanderpool; 1♂, WAU.RAT, Ravensthorpe, 33°35'S 120°04'E, 10.i.2003, Moulds, Marshall, Hill & Vanderpool; 1♂, AU.WA.MOJ.01, 56 km S Norseman, 4.8 km SW Esperance Hwy, 32°38.551'S 121°30.428'E, 7.ii.2009, K. Hill, D. Marshall, C. Simon Lab voucher, legs in EtOH, specimen recorded (MSM). **SOUTH AUSTRALIA:** 13♂, 55 km ESE Kimba, on Kimba/Iron Knob road, 12.xii.1995, M.S. & B.J. Moulds, K.A. Kopestonsky; 2♂, AU.SA.WUW.01 and AU.SA.WUW.02, 3.5 km W Wudinna, 33°2.507'S 135°27.001'E, 5.ii.2009, 92 m, K. Hill & D. Marshall, C. Simon



Figs 9–12. *Auscala flammea* **sp. n**. Male pygofer and internal genitalia; (9), viewed laterally from the left; (10), viewed ventrally; (11), aedeagus, viewed laterally from left; (12), apex of theca, ventral view. Characters include: as, anal styles; bp, basal plate; bpl, basal lobe of pygofer; cl, clasper; db, dorsal beak; en, endotheca; ps, pseudoparameres; pyg, pygofer; unc, uncus; upl, upper lobe of pygofer; vs, ventral support. Specimen from Brookton H'way, 50 km SE Kelmscott, WA, 33°14'S 116°26'E.

Lab voucher, legs in EtOH, specimen recorded; 1♂, AU.SA.PBE, Barrier Hwy, 2.3 km NE rd to Peterborough, 521 m, 32°56.412'S 138°59.476'E 9.i.2011, K. Hill & D. Marshall, C. Simon Lab voucher, song heard; 1♂, 32 km E Kimba, 33°05'S 135°45'E, 21.i.1986, G. & A. Daniels; 1♂, approx. 20 km SE Burra, 33°42'S 139°06'E, 6.i.1996, M.S. & B.J. Moulds (MSM); 1♂, Australia SA, 29 km E Kimba, 33°07'28"S 136°44'05"E, 7.i.2020, A. Stolarski, mallee woodland, 177-0001; 1♂, Australia SA, 82 km W Kimba, 33°02'35"S 135°48'40"E, 7.i.2020, A. Stolarski, mallee woodland, 177-0002; 1♂, 30 km E by N of Swan Reach, S. Aust., 34°31.478'S 139°54.879'E, 21.xii.2013, M.A. Hura (LWP).

Other material examined. 1♀, "New Holland, Goding, 12.vii.[19]04", I5035a. (SAMA database 20-014673) (SAM).

Additional song recordings: Australia SA, Clements Gap, 33°29'08"S 138°4'29"E, 2.xi.2016, L. Popple.

Description of male holotype (Figs 1, 2, 5–7, 9–12). Head including eyes about as wide as mesonotum but narrower than lateral angles of pronotum; black with ochraceous triangular spot at posterior midline, ochraceous rectangle between ocelli and eyes; posterior margin ochraceous; ocelli pink; supra-antennal plate meeting or nearly meeting eye; with ochraceous spot lateral to antennae; eyes light brown. Postclypeus broadly rounded transversely across ventral midline, an ochraceous triangular marking above, broadly black along anterior and posterior midline, ventral surface ochraceous along midline groove, becoming pink laterally, transverse ridges black, lorum pink, gena black. Anteclypeus black. Rostrum ochraceous tending black distally, extending beyond the mid coxae. Antennomeres black. Thorax. Pronotum light brown to black with ochraceous markings along anterior half of midline, lateral and parapsidal fissures variably ochraceous, ridges mainly black, black centrally adjacent to pronotal collar; pronotal collar dark brown centrally and along posterior margin, black over remainder, lateral margins with mid-lateral and anterior "teeth", black with ochraceous spot along anterio-lateral margin. Mesonotum ochraceous to dark brown centrally, lateral and submedian sigilla black, a prominent ochraceous, oval spot laterally, sloping dorsally, cruciform elevation black, brown laterally between arms, scutal depressions black; Metanotum black, ochraceous along posterior margins. Legs black to brown, basisterna 2 black, meron red, coxae red, trochanter red. Femora striped black and pale brown, pale brown distally, spines black; tibiae mainly black with narrow ochraceous band adjacent to basal joints, hind tibiae ochraceous distally; fore tarsi mainly black, mid and hind tarsi with ochraceous tips, claws black at tips. Meracantha mainly black, ochraceous laterally, triangular, pointed posteriorly, marginally overlapping anterior half of opercula. Wings hyaline. Fore wing with fused stem of veins M and CuA completely fused before meeting basal cell; costal vein dark brown yellow tending brown distally, vein RA1 aligned closely with Sc for its length, other veins dark brown to black, clavus and cubital cells fused, darkened over proximal quarter, with 8 apical cells; basal cell translucent, basal membranes fiery red, some SA specimens dull red. Hind wing with 6 apical cells; venation brown; prominent white plaga covering entire anal cells and jugum. Opercula black anteriorly,

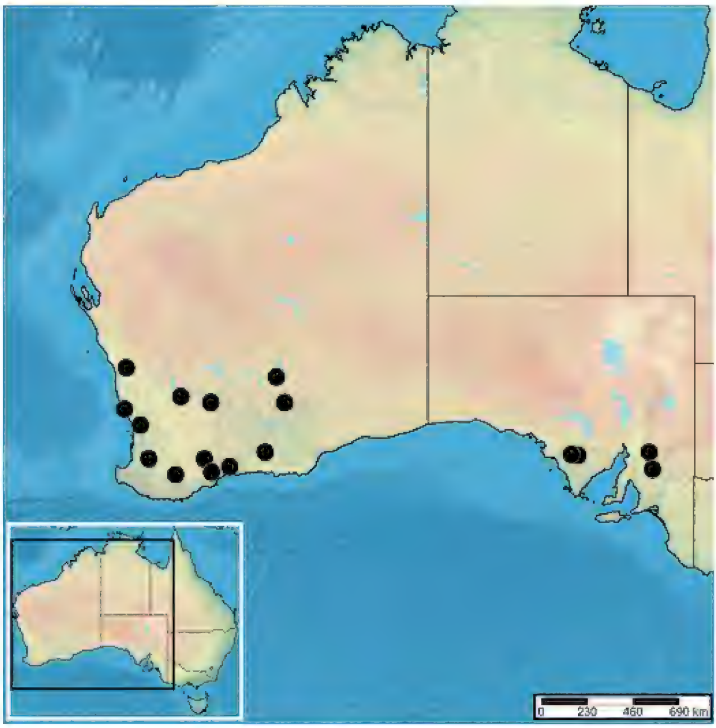
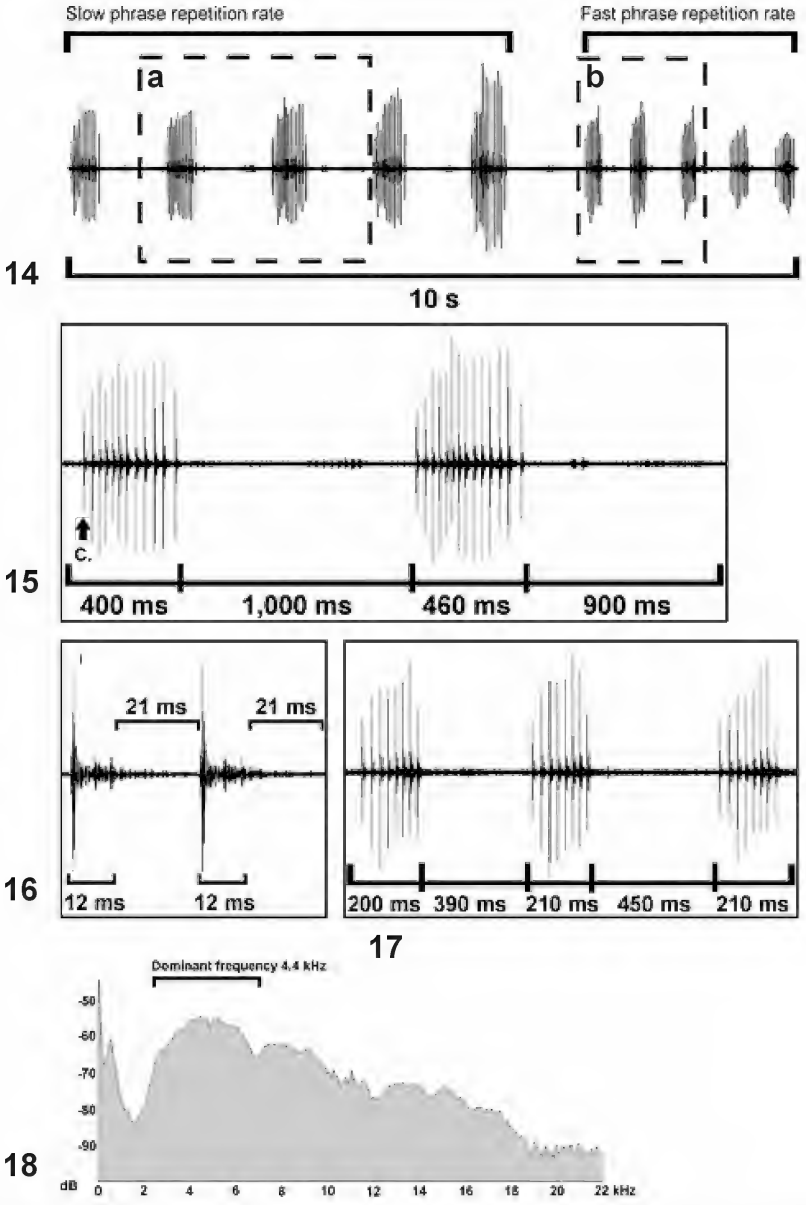


Fig. 13. Map of southern Western and South Australia showing the geographical distribution of *A. flammea* **sp. n.** (closed circles).

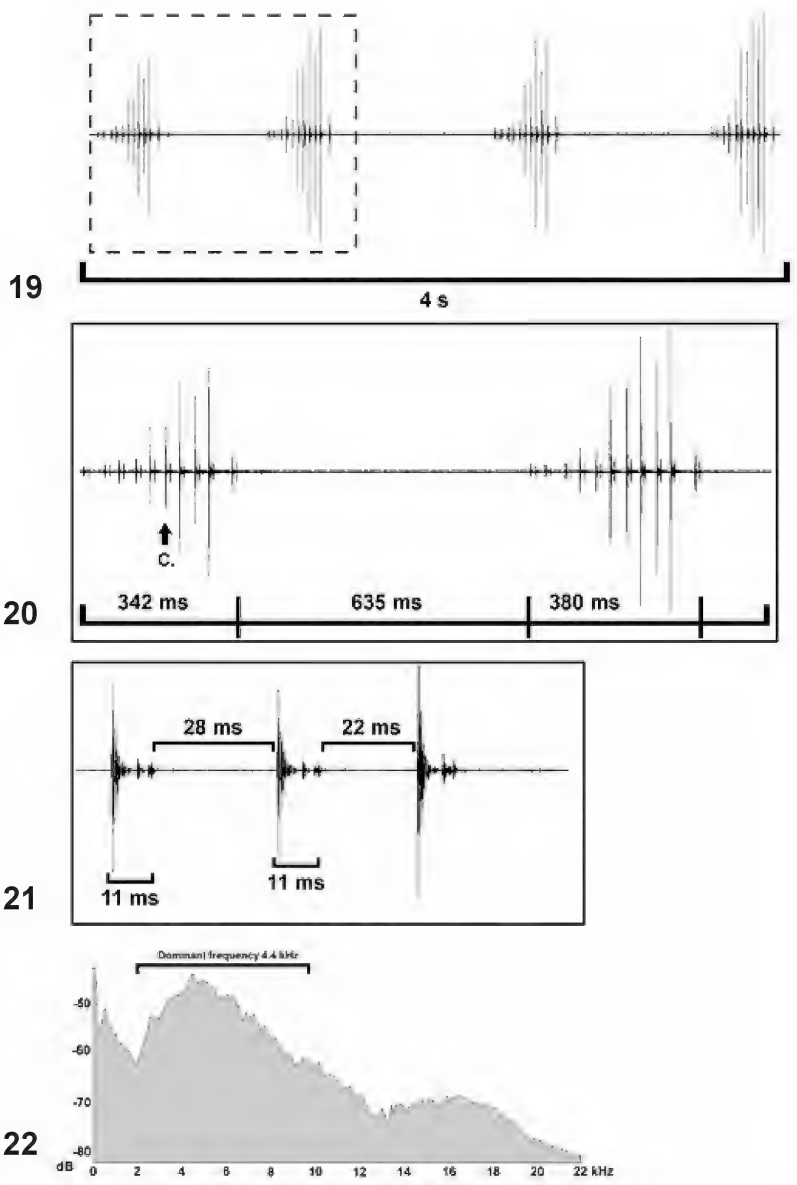
pale red posteriorly, rounded centrally, spatulate, almost reaching distal margin of tympanal cavity, bulbous over base (epimeron 3); clearly separated (Fig. 6). Timbals with six long brown ribs, pale membrane; long ribs 1–4 extending across the width of timbal membrane, long rib 5 discontinuous over ventral half of timbal, long rib 6 restricted to dorsal half of timbal, basal dome large; brown, grooved over lateral third (Fig. 5).

Abdomen. Tergite 1 black, narrow along dorsal midline, red along timbal cavity; tergite 2 about as wide as tergite 3, tergites 2–7 black, red-brown posteriorly, midline black. Tergite 8 with central black semicircle, red-brown over remainder; sternite I black, narrow, sternite II black with red over posterior margin, sternite III black centrally, red over lateral two-thirds, sternites IV–VI becoming increasingly black, red laterally, sternite VII black centrally, orange red over posterior and lateral half, sternite VIII ochraceous, with whitish pubescence (Fig. 7).

Genitalia (Figs 9–12). Pygofer dorsum black, dorsal beak brown, ochraceous over remainder, in lateral view rounded anteriorly, upper lobe moderately developed, basal lobes continuous, rounded, in ventral view ovoid, with both lobes inside outer margin of pygofer. Anal styles tipped red-brown. Uncus medium, flattened,



Figs 14–18. Male calling song structure of *Auscala flammea* **sp. n.** illustrated in waveform plots. Each lower plot (Figs 15–17) is expanded from the one above, to illustrate the finer temporal structure. (18) Spectrogram of song frequency. This specimen was recorded at Oldfield River, 35 km E Ravensthorpe, WA (33°40'S 120°40'E) by David Marshall.



Figs 19–22. Male calling song structure of *Auscala spinosa* (Goding and Froggatt), illustrated in waveform plots. Each lower plot (Figs 20, 21) is expanded from the one above, to illustrate the finer temporal structure and waveform. (21) Finer structure of the syllables from Fig. 20. (22) Spectrogram of song frequency. This specimen was recorded at Pyramid Creek, Victoria (34°44'S 143°59'E) by David Marshall.

"dolphin-beak" shaped in lateral view. Claspers well developed, beak-like in lateral view, anterior segment ellipsoid in ventral view, closely surrounding aedeagus; a swelling on inner margin. Aedeagus with basal plate undulated in lateral view, in dorsal view short and broad, apically "sausage-shaped" directed anteriorly from thecal shaft; thecal shaft mainly straight, hollow; dorsal pseudoparameres unfused, in dorsal view turning medially before gradually diverging, in lateral view directed upwards from thecal shaft; shaft with proximal half free from ventral support; endotheca exposed, fleshy, ventral support around half the length of pseudoparameres; seminal vesical opening towards apex of theca.

Female (Figs 3–4). Head and thorax similar to male.

Abdomen. Similar to male except for the following characters. Tergites with posterior red-brown margins less pronounced. Sternites black with orange-brown lateral margins, sternite VII red with small black spot either side of midline, abdominal segment 9 orange brown along dorsal midline, black lateral stripe, yellow-brown over remainder with lateral black spot, dorsal beak black. Ovipositor sheath long, dark brown to black, extending 1.0–1.5 mm beyond apex of abdomen; ovipositor dark brown, black at tip.

Variations across distribution. Across its distribution, males of *A. flammea* **sp. n.** from South Australia are larger, being >29 mm body length (1.0–1.5 mm longer than WA specimens) and around 1 mm wider than their WA counterparts. They are also much larger than the SA specimens of *A. spinosa* (ca. 25 mm body length) recorded by Haywood (2005). The SA specimens of *A. flammea* **sp. n.** are lighter coloured, with dark brown markings dorsally, pink to dark orange basal membranes and lighter red coloration on the posterior tergites. Females of *A. flammea* **sp. n.** exhibit consistent markings and sizes across the species distribution in Western Australia, but definitive specimens are lacking from South Australia.

Measurements. Range and mean (in mm) for 11 males and 6 females includes smallest and largest of available specimens. Length of body: male, 25.1–31.4 (27.9); female (including ovipositor), 31.3–32.8 (32.2). Length of forewing: male, 27.8–32.1 (30.8); female, 34.0–36.1 (34.3). Width of forewing: male, 9.0–11.1 (9.9); female, 10.4–11.2 (10.7). Width of head (including eyes): male, 7.4–8.1 (7.8); female, 8.0–8.5 (8.3). Width of pronotum (across lateral angles): male, 7.8–9.1 (8.4); female, 8.4–9.4 (8.8). Abdominal width (across segment II): male, 7.8–9.6 (8.8); female, 7.8–8.6 (8.2). Ovipositor length: 9.8–11.9 (10.8).

Distinguishing features. The brilliant red markings on the basal membranes and the orange-red coloration on the abdomen, encompassing posterior margins of the opercula, tergites, tergite 8 and lateral borders of sternites clearly distinguishes *A. flammea* **sp. n.** from *A. spinosa*, whose coloration over the analogous areas is cream to pale brown. A distinctive feature of *A. spinosa* is the cream coloration of tergite 8, which is dark orange to red in *A. flammea* **sp. n.** (Fig. 7). Several features of the genitalia of *A. flammea* **sp. n.** also differ from *A. spinosa*: 1, the basal

pygofer lobe is less defined; 2, the claspers are more elongated anteriorly; and 3, the uncus appears annular in ventral view. Comparisons of the respective calling songs indicate, that while structurally similar, the song of *A. spinosa* appears to lack the "fast phrase repetition rate" produced by *A. flammea* **sp. n.** (see below).

Etymology. This species is named "*flammea*" after the fiery red coloration of its basal membranes.

Habitat and Distribution. *Auscala flammea* **sp. n.** is quite widely distributed throughout south-western WA to around 800 km E Perth. There are no records from across the Nullabor Plain and western South Australia, but an additional population exists on the Eyre Peninsula and north of Adelaide (Fig. 13). Populations may be quite large in typical habitat (Fig. 8), and the species readily comes to UV light. *Auscala flammea* **sp. n.** occurs in natural vegetation types of mallee, savannah woodland and dry sclerophyll forest that have an annual average rainfall between 250 and 800 mm (Fig. 1, https://www.agric.wa.gov.au/climate-change/climate-trends-western-australia). In Western Australia, males call from the upper branches of scrubby eucalypts (such as *Eucalyptus wandoo* Blakely) and from smaller shrubs when populations are large. In South Australia, most specimens have been captured from mallee woodland. Specimens have been collected from November to January. It is possible with the close proximities of specimens reported in South Australia, that populations of *A. flammea* **sp. n.** may overlap with *A. spinosa* in that State.

Calling song of A. flammea **sp. n.** (Figs 14–18).
The calling song of *A. flammea* **sp. n.** is described from recordings generously provided by D.C. Marshall and K.B.R. Hill from four localities, with an example from near Ravensthorpe illustrated in Figs. 11–15. An additional recording kindly made available by L. Popple from Clements Gap, South Australia, was also analysed. The calling song of *A. flammea* **sp. n.** consists of a deep repetitive rattle at either a slow (Fig. 14a) or fast phrase repetition rate (Fig. 14b). Upon close examination, each rattle is a phrase comprising 10–14 echemes (Fig. 15). An echeme consists of three (or sometimes four) coalesced syllables and ranges from 11–13 milliseconds (ms) duration with a very brief period of silence after each echeme of 12–25 ms duration (n = 4). Physiologically, this may result from an initial inward click of each timbal followed by its asynchronous "rebound out-click" (suggested by L. Popple). In the recording from Clements Gap, the first two of the four syllables are coalesced. A phrase typically lasts between 400 and 460 ms duration and is completed by a period of silence ranging from 715 to 1,300 ms duration (Fig. 16). Under the fast phrase repetition rate, each phrase is shorter (around 180 to 210 ms duration), comprising 8 echemes and each phrase completed by period of silence between 322 and 450 ms duration (Fig. 17). The spectrogram of the calling song indicates a high amplitude frequency plateau between 2.5 and 7.0 kHz with a dominant frequency of 4.4 kHz (Fig. 15). The features of the song were similar from recordings near Windunna (South Australia) and Pallingup River and Norseman in Western Australia.

Calling song of A. spinosa (expanded from Haywood, 2006) (Figs 19–22).

The song of *A. spinosa* also consists of repetitive rattle phrase comprising between 7 and 11 echemes (n = 3; Fig. 19). An echeme comprises three adjoining (but separated) syllables that are between 10 and 15 ms duration. Each phrase of *A. spinosa* is between 342 and 480 ms duration with a variable period of silence from 635 to 3,100 ms duration between phrases (Figs. 20, 21). The spectrogram of *A. spinosa* indicates a high amplitude frequency plateau between 2.5 and 6.3 kHz with a dominant frequency of 4.4 kHz (Fig. 22). These features of the song of *A. spinosa* were consistently apparent in several recordings examined from across its range in Victoria (Pyramid Creek and Stanley), Queensland (Lake Broadwater) and New South Wales (Windsor Downs Nature Reserve).

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NEW HOST PLANTS AND DISTRIBUTION RECORDS IN SOUTH AUSTRALIA FOR *MICROCASTALIA* HELLER (COLEOPTERA: BUPRESTIDAE) WITH A SUMMARY OF THE TAXONOMIC HISTORY OF THE GENUS

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Abstract

Microcastalia Heller, 1891 is an endemic Australian genus currently comprising two species. We review its taxonomic history—from past placements with South American genera, to recent treatments placing it in an older Australian lineage. The first host plant records for *Microcastalia* are reported and their significance is discussed. Various life stages of *M. globithorax* (Thomson, 1878) were found at diverse locations in three shrub species of family Santalaceae: *Choretrum chrysanthum, C. glomeratum* and *Leptomeria aphylla*. Continuity of frass-filled tunnels indicates that larvae feed downwards from upper branchlets to pupate near the plant base, which is supported by observations of ovipositing behaviour. *Microcastalia scintillans* (Carter, 1924) is first reported for South Australia from dead salt lake collections and a live specimen.

Key words: *globithorax*, *scintillans*, *Choretrum*, *Leptomeria,* breeding, larva, oviposition behaviour

Introduction

Buprestid larvae are mostly wood borers, with larval food plants unknown for the great majority of the c. 1300 Australian species (ABRS 2020). *Microcastalia* Heller, 1891 as currently understood (Bellamy and Peterson 2000, ABRS 2020), is an endemic Australian genus of two species, *M. globithorax* (Thomson, 1878) and *M. scintillans* (Carter, 1924), both being uncommon and confined to southern Australia. The genus has for many years been the subject of discussion over its biogeographic and phylogenetic relationships due to its general resemblance to extra-Australian taxa and previous classifications with them.

Matthews' (1985) account of *Microcastalia* in South Australia (SA) noted two specimens of *M. globithorax* collected from 'Kangaroo Island' in 1878, the only ones from that State at the time with a specific location. He remarks: 'The rediscovery of this species, and the determination of its food plant, would be matters of great interest'. Bellamy and Peterson (2000) described *M. globithorax* as 'apparently rather rare in collections and enigmatic in nature and with no published records on plant associations that we are aware of'. The compilation of buprestid host plant records by Bellamy *et al*. (2013) reported none for *Microcastalia.*

Rarity

Online museum and other publicly available records give a distribution for *M. globithorax,* from south-western Western Australia (WA), through SA and Victoria to the extreme south-eastern corner of Queensland. Despite its wide range, the species is infrequently collected. There is a high proportion of early collections with only general locations (such as Australia, or South Australia) and

a scattering of more geographically precise recent records, but none have host plant or habitat information. Only one specimen of *M. globithorax* was added to the South Australian Museum (SAMA) collections since Matthew's (1985) account – a dead individual from a salt lake on eastern Eyre Peninsula. Burns and Burns (1992) review of buprestid occurrences in Victoria reported only a single record of *M. globithorax* in their compilation of 5735 buprestid records from seven museums and 15 private collections. Golding (2008), who collected dead specimens from salt lakes in south-western WA, described it as rarely seen.

Microcastalia scintillans appears to be even more rarely collected, and hitherto known only from southwestern WA. Over many years of collecting in WA, T.M.S. Hanlon and M. Powell (pers. comm., 2020) have encountered only a few salt lake specimens of *M. scintillans* and found neither species on plants. Hanlon however, recorded a total of 17 *M. globithorax* in yellow bucket traps (but none in blue or red) set on eight occasions from 2013 to 2019 at 10 km N of Leeman, WA.

Taxonomic background

Microcastalia has had a chequered taxonomic history based on differing views of its phylogeny and biogeography. The type species, *M. globithorax,* was described by Thomson (1878) in *Castalia* Gory and Laporte, 1839, a preoccupied name now replaced by *Strigoptera* Dejean, 1833. This genus of subfamily Polycestinae has an essentially Indo-Malayan distribution. The second species, *M. scintillans* was also described in *Castalia,* by Carter (1924). Later, Carter (1929) transferred it to *Polycesta* Serville in Dejean, 1833, then tentatively (Carter 1940) to another polycestine genus, *Polycestella* Kerremans, 1902, before it was finally transferred to *Microcastalia* by Bellamy and Peterson (2000).

Castalia globithorax Thomson, 1878 was removed to the monotypic *Microcastalia* erected by Heller (1891), which in Kerreman's (1906) monograph was placed alongside *Castalia* in tribe Polycestini. Its placement in that tribe (later to be raised to subfamily as Polycestinae) was endorsed by Théry (in Carter 1929). *Microcastalia* remained there until Cobos (1978) asserted that it clearly belonged in subfamily Buprestinae even using the earlier authors' own keys. He was struck by the remarkable external resemblance of *M. globithorax* to *Buprestis (Goryola) sphericollis* Laporte and Gory, 1836 but with an aedeagus and shortened ovipositor more like that in *Ditriaena.* This led him to expand the concept of *Microcastalia* by including the Central American *Ditriaena* and the related southern South American *Goryola* Cobos, 1975 as subgenera within it. Cobos still recognised strong extra-Australian affinities but they were now realigned from the Indo-Malayan to Neotropical region.

In referring to the broad treatment by Cobos (1978) which gave *Microcastalia* a distribution centred in South and Central America, Matthews (1985) proffered that the distinctiveness of *M. globithorax* at subgeneric level precluded the possibility that it might be introduced to Australia. It was in this context that he suggested that discovery of its larval host would be of particular interest.

Table 1: Summary of *Microcastalia globithorax* host plant and breeding record vouchers.

Site	Location	Breeding evidence	Host	Date
1	Barwell CP, Eyre Peninsula (EP)	• dead adult remains PL3574 • (pre-)ovipositing behaviour PL3573 • fresh exit holes and pristine adults PL3572A–E, PL3573	*Choretrum chrysanthum* PJL 2890, 2891	10 Feb 2016
2	Hambidge CP, EP	• mid instar larva PL3636B • late instar larvae PL3631, PL3636A matching site 3 • prepupae PL3634, PL3635 consistent with above • basal exit holes and tunnels matching sites 1 and 3	*C. chrysanthum* PJL 3083, 3085	4 and 5 Nov 2016
		• dead non-emerged adult PL3967	*C. chrysanthum* PJL 3212	15 Oct 2017
3	Crosby Rd, near Malinong, South-east SA (SE)	• live non-emerged adult PL3778 • adult reared from late stage pupa PL3776 • late instar larvae PL3777A, D consistent with above	*Choretrum glomeratum*	21 Jan 2017
		• adults on foliage PL3807, PL3808A, B	*C. glomeratum* PJL 3115, 3116	2 Feb 2017
		• prepupa PL4015	*C. glomeratum* PJL 3273	16 Nov 2017
4	Hawks Nest Well, SE	• live non-emerged adult PL3810	*C. glomeratum*	4 Feb 2017
5	NW of Port Kenny, EP	• live non-emerged adult PL4104 • larvae PL4105, PL4106 • pupa PL4111	*C. glomeratum* PJL 3286, 3288, 3289	31 Dec 2017
6	NW of Port Kenny, EP	• pupa PL4113	*C. glomeratum* PJL 3291	31 Dec 2017
7	Near Binnie Lookout, SE	• larvae PL4127A, B	*C. glomeratum* PJL 3296	18 Jan 2018
8	SW of Yumali, SE	• larva PL4188	*Leptomeria aphylla* PJL 3312	10 Jun 2018
9	NNE of Culburra SE	• larva PL4238	*C. glomeratum* PJL 3347	18 Sep 2018

Hołyński (1993) returned *Microcastalia* to the Polycestinae, a move rejected by Bellamy and Peterson (2000) who argued also against a close relationship with the two South American buprestine subgenera on a variety of morphological grounds. These they combined in a separate reinstated genus, leaving *Microcastalia* as endemic in Australia, and noting that no other buprestine genera were shared between the Australian and Neotropical regions. They deemed it a truly indigenous taxon and posited that nothing 'remotely similar' to *M. globithorax* was known from any other part of the world. Instead, they drew attention to similarities with the Australian genera *Neobubastes* Blackburn, 1892 and *Notobubastes* Carter, 1924, proposing the latter as a possible sister group. Their view that *Microcastalia* might form part of an old Australian lineage is consistent with Bílý and Volkovitsh (1996) who saw an autochthonous origin for the majority of Australian genera and considered the external adult resemblance to non-Australian genera as a result of parallel and convergent evolution.

A study of antennal structure by Volkovitsh (2001) supported these views, finding that *Microcastalia* had 'nothing in common' with Polycestini, and also differed greatly from *Ditraena.* Volkovitsh placed *Microcastalia* in its own 'generic group', which he included with tribes Bubastini, and Stigmoderini, in a separate Australian 'Stigmoderinioid branch' of the Buprestinae.

The classification adopted by Bellamy *et al.* (2013) has *Microcastalia* in subfamily Buprestinae but without tribe, listing it together with *Buprestina* Obenberger, 1923, *Notobubastes* and *Neobubastes* as 'Genera *Incertae Sedis'* pending more complete testing of higher level phylogenetic hypotheses. Lawrence and Lemann (2019) followed this apart from having *Neobubastes* in tribe Pterobothrini of Volkovitsh (2001), citing Bílý and Powell (2017) whose unexplained assignment of it there is contrary to Volkovitsh's schema.

Host plant association

In this paper we record *Choretrum* R.Br. (Santalaceae) as a host plant for *Microcastalia.* This genus of hemiparasitic shrubs with scale-like, caducous leaves is endemic to southern Australia (Hewson 1984) and has seven described species (CHAH 2020). It has not previously been recorded as a host plant for Buprestidae (Bellamy *et al.* 2013).

Methods

Choretrum bushes were surveyed for signs of buprestid larval activity on the Eyre and Fleurieu Peninsulas, the southern Flinders Ranges and the upper south-east of SA. Excepting in the Flinders Ranges, foliage was also examined, and/or swept with an insect net, in mid-summer when any adult *Microcastalia* would have emerged.

All host plants were identified by PJL, and vouchers assigned numbers in the P.J.Lang collection series (indicated here by 'PJL') were lodged at the State Herbarium of South Australia (AD). Pinned buprestid adults, and immatures in

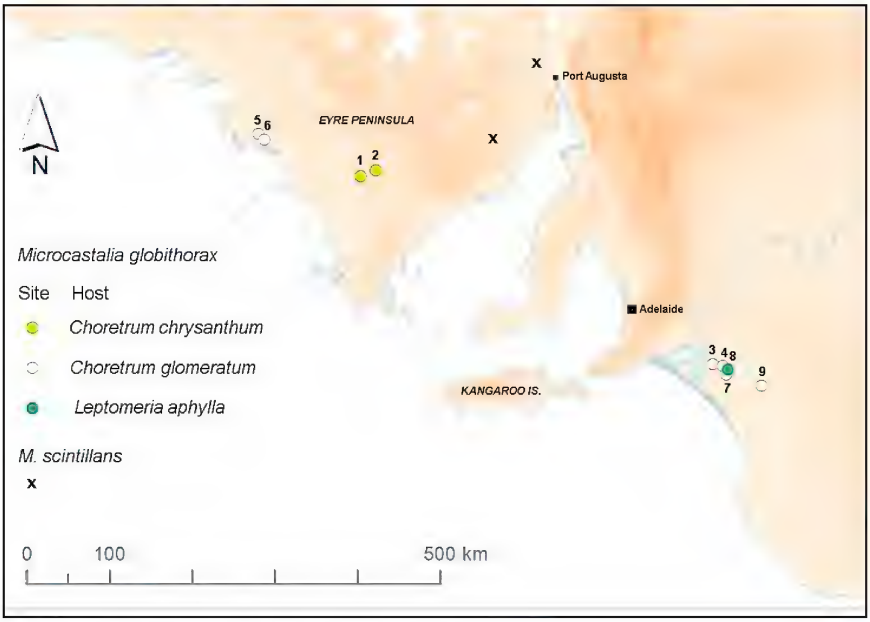


Fig. 1. Locations of new *Microcastalia* records in southern South Australia, with their associated host plants.

absolute ethanol, have voucher numbers with the prefix PL and are held in the private collection of PJL for eventual lodgement in SAMA.

Specimens were photographed with a Sigma 50 mm 1:2.8 macro lens on a digital SLR camera. This was mounted on a height-adjustable arm for some stacked images which were processed using Helicon Focus 6 software. Backgrounds were edited to white and image contrast was adjusted using Jasc Paintshop Pro 7.

Specimen measurements were made with a calibrated eyepiece scale and are the maximum length and width, excepting adult beetle length which is from the frons to the apex of the elytra.

Observations

Breeding was discovered at nine sites in southern South Australia on three different plant hosts (Fig. 1). Table 1 summarises adult and larval host plant usage with specimen voucher numbers.

Choretrum chrysanthum F.Muell. (Yellow Sour-bush)

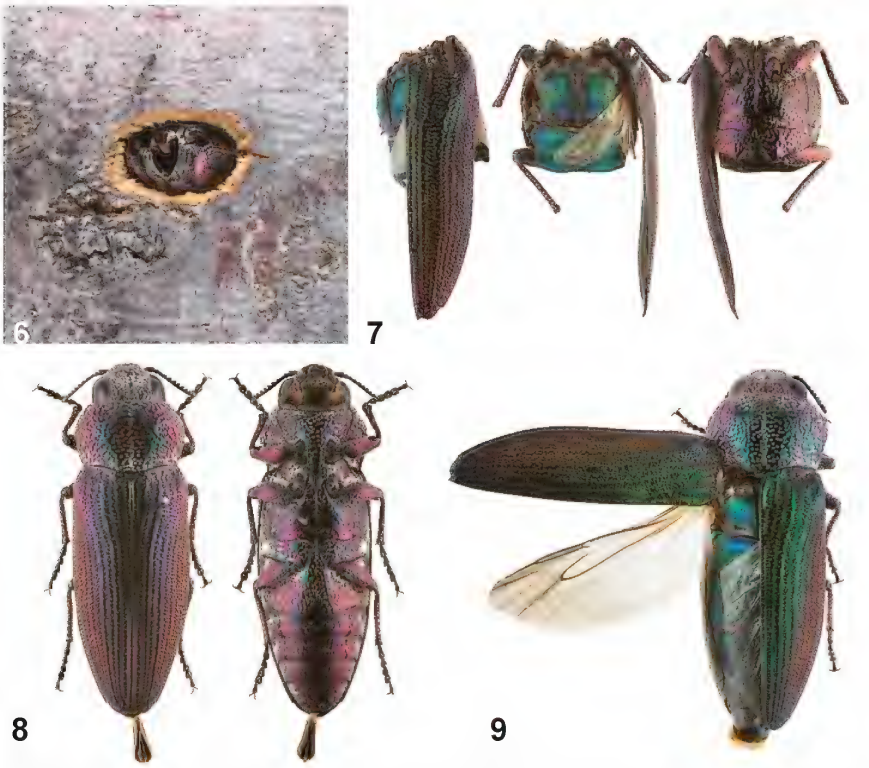
Adults of *Microcastalia globithorax* were observed by PJL on 10 Feb 2016 on two neighbouring bushes (Figs 2, 3) of *Choretrum chrysanthum* 1.2 and 1.5 m tall and about 15 m apart, growing in intact mallee vegetation in Barwell Conservation Park (CP), northwest of Lock on Eyre Peninsula (Site 1). They were alighting

Figs 2–5. *Choretrum chrysanthum*, site 1. (2, 3) The bushes on which *Microcastalia globithorax* adults were observed: (2) bush 1, 1.2 m tall, showing surrounding mallee vegetation; (3) bush 2, 1.5 m tall. (4) Fruiting branchlets with female *M. globithorax* (PL3572E), 16.8 mm long. (5) Fresh exit holes near base of the trunk on bush 1.

and moving about on the upper branchlets that constitute the effectively leafless 'foliage' (Fig. 4). Over a three hour period, nine individuals of *M. globithorax*, both male and female, were observed on the two bushes.

Seven freshly made exit holes were found on these bushes, and another on a third bush, the nearest neighbouring *Choretrum* 35 m away. The holes (Fig. 5) were lenticular-ellipsoid in shape, had sharp edges with pale unweathered wood exposed inside, and measured 4.8–5.5 by 3–4.5 mm, consistent with the beetles' girth. Four were on a short main trunk 50–100 mm above ground, and four towards the base of major branches less than 150 mm above ground. One hole was blocked by a dead, partly-emerged beetle (Figs 6, 7), which closely matched adults collected from foliage (Figs 8, 9).

At least two females displayed apparent ovipositing or pre-ovipositing behaviour on the two closest bushes. They moved up and down branches continuously for 10 to 15 minutes, with their ovipositor exserted and frequently touching the



Figs 6–9. *Microcastalia globithorax*, site 1. (6, 7) Dead non-emerged adult remains (PL3574): (6) in exit hole on lower branch of *Choretrum chrysanthum* bush 2; (7) after removal and cleaning: prothorax (with loosely attached elytron) in lateral, dorsal and ventral view. (8, 9) Specimens caught as live adults on foliage: (8) male (PL3572B) 12.1 mm long. (9) female (PL3573) 16.1 mm long.

surface (Fig. 10). After alighting on outer canopy branchlets, a beetle followed stems downwards, sometimes all the way onto the trunk c. 60 mm in diameter and within 30 mm of ground level, but mostly to the bases of major branches c. 20 mm thick which diverged from the trunk at 100–150 mm above ground. From there it crawled back up onto another branch system, following it upwards onto outer stems at least as narrow as 10 mm diameter but always staying well within the canopy edge. This was repeated many times, with the beetle crawling down to the base of the bush by a different route each time. Occasionally it stopped briefly with its ovipositor positioned in a depression or irregularity on the stem as if depositing an egg, but none were detected when the stems were subsequently searched.

This occurrence of *M. globithorax* was localised, with fresh exit holes and/or live adults only detected on the three adjacent bushes spanning an extent of 50 m.

Examination of more than 40 *Choretrum chrysanthum* bushes scattered sparsely along several kilometres of nearby tracks and roadsides revealed no more adults, or evidence of breeding activity apart from a few bushes with old and weathered exit holes.

The major branch with the dead remains was removed and the exit hole was found to be connected via the pupal chamber to a tunnel in the centre of the stem filled with fine compacted wood frass. This formed a single continuous central frass core that extended from its termination several centimetres below the chamber, upwards through several orders of branching into outer stems 10 mm thick.

Evidence of *M. globithorax* breeding in *C. chrysanthum* at a second location on Eyre Peninsula was discovered by PJL in early November 2016 in Hambidge CP (Site 2), 17 km ENE from the Barwell CP occurrence. Mid and late instar larvae to 30 mm long and a 24.6 mm prepupal larva (Fig. 11), suspected to be *M. globithorax,* were extracted from stems. They were subsequently found to match the larvae associated with a confirmed breeding occurrence of *M. globithorax* at Site 3 (described below). A frass-filled central tunnel was traced for 0.5 m from the 20 mm thick branch where a larva was found, through to an upper stem 11 mm thick where the trail was lost. The site was revisited in October of the following year and a dead adult (Figs 12, 13) was obtained from a bush that had yielded a larva and prepupa on the first visit. It was situated near ground level at the base of a branch which had been alive on the first visit but now bore dead foliage and comprised mostly dead wood.

Choretrum glomeratum R.Br. (White Sour-bush)

The discoveries on Eyre Peninsula prompted searches of a related species, *Choretrum glomeratum,* in the upper south-east of SA. On 21 January 2017 at Site 3 near Malinong, AMPS found two late instar larvae (24 and 30 mm long) and an advanced pupa (Fig. 14) in the base of one bush, and a live non-emerged adult in the base of another. The pupa was reared by PJL, and an adult *M. globithorax* (Figs 15, 16) eclosed on 28 January 2017. Initially it seemed atypical in its somewhat coppery coloration and in lacking the fine, fluffy excresence of white material that is usually very obvious within larger puncta. However 11 days later when fully hardened, the pronotum had changed to the normal blackish-purple and the white material had developed.

Three adults were also collected at Site 3 by AMPS and PJL from the foliage of *C. glomeratum* bushes on 2 February 2017, and a revisit by AMPS on 16 Nov 2017 uncovered a prepupa in a basal stem.

Examination of plant material from Site 3 again revealed a continuous column of compacted frass in a central tunnel. Here it was traced for over 0.6 m from its commencement just below a prepupa in a branch 19 mm thick, through several orders of branching, to its termination about 150 mm short of the outer tip of foliage in a branchlet only 2.1 mm thick with a frass core 0.4 mm across (Fig. 17).

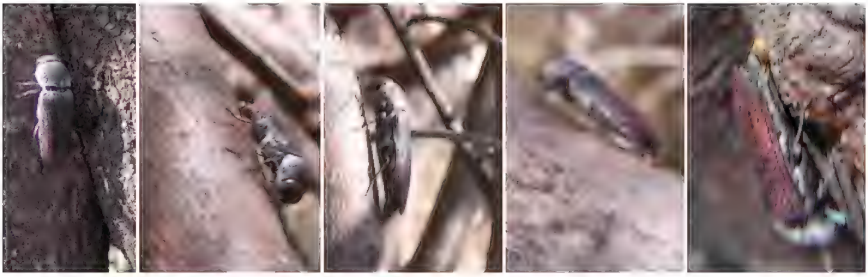
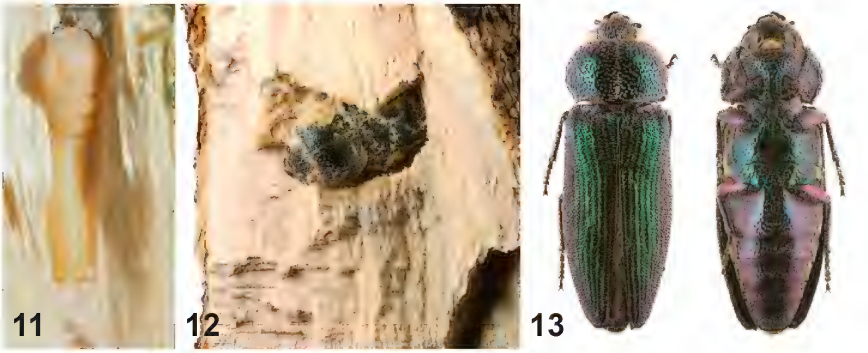


Fig. 10. *Microcastalia globithorax* exhibiting (pre-)ovipositing behaviour, with ovipositor extended, in various positions on trunk and branches of *Choretrum chrysanthum* at site 1.



Figs 11–13. *Microcastalia globithorax* in *Choretrum chrysanthum*, site 2. (11) Prepupal larva (PL3634) 24.6 mm long. (12–13) Dead non-emerged adult (PL3967), 15 mm long: (12) in dead stem base 31.5 mm diameter; (13) after removal and cleaning, in dorsal and ventral view.

Figs 14–16. *Microcastalia globithorax* (PL3776) male from *Choretrum glomeratum*, site 3: (14) as advanced pupa with adhering larval exuvia in dorsal and ventral view; (15) as adult prior to eclosure; (16) as recently eclosed adult, 12.6 mm long, still with pupal exuvia and showing coppery reflections in dorsal and ventral view.

Further finds made by AMPS in *C. glomeratum* from this region include: a second live non-emerged adult extracted from a dead branch of an otherwise live bush (Site 4), two late stage larvae 25 and 26 mm long (Site 7); and a larva 36 mm long from a stem base and presumed to be a final instar (Site 9).

Breeding evidence in *C. glomeratum* was also found by AMPS on Eyre Peninsula at two sites 8 km apart near Port Kenny on the west coast. Each yielded a pupa (Fig. 18) clearly identifiable as *M. globithorax* and confirmed at Site 5 by its association with larvae and a live non-emerged adult (Fig. 19). That pupa was situated c. 10 mm above ground level in a chamber extending to 4 mm from the stem surface. The pupa at Site 6 came from an exposed upper root of a tree which had fallen over and remained alive; its pupal chamber extended to 1.6 mm from the root surface. The larvae were again consistent in morphology, matching those from *C. chrysanthum* and *C. glomeratum* in south-eastern SA.

Searches of *C. glomeratum* populations by PJL south of Adelaide on the Fleurieu Peninsula at Strathalbyn, Finniss and near Ashbourne found no evidence of *Microcastalia* activity.

Leptomeria aphylla R.Br. (Leafless Currant-bush)

A single advanced stage larva 28 mm long (Fig. 20), matching those found in *Choretrum* (Fig. 21), was discovered in the base of a *Leptomeria aphylla* by AMPS on 12 Jun 2018 southwest of Yumali in the upper south-east region (site 8). Nearby bushes displayed no signs of *Microcastalia* activity.

Larval morphology

The larvae (Figs 20–22), from six sites (Table 1) are consistent in morphology, distinctive and easily recognisable. Their concurrence with comparable prepupal and pupal stages as well as dead and live non-emerged adults, leaves little room to doubt their identity as *M. globithorax*. They are of the Buprestinae type with the usual much enlarged and somewhat flattened prothoracic segment. Their large size (up to 36 mm long) excludes the smaller local genera from this subfamily, and the three common and species-rich larger genera, *Melobasis, Castiarina* and *Temognatha*, can be excluded on morphology. The uniramous prosternal groove rules out *Melobasis* where it is described as '3-armed' by Bílý and Volkovitsh (2005) based on the evidence of four species (and confirmed by PJL for four other SA species). The *M. globithorax* larvae also differ greatly from *Castiarina* and *Temognatha* in their disproportionately larger prothorax, finer and less obvious hairs, overall paler body colour, and pronotal and prosternal plates non-coloured in and around grooves and lacking extensive areas of asperities.

A striking feature of *M. globithorax* larvae is the pair of prominent brown crescentic-semicircular mesothoracic spiracles visible from the ventral and lateral sides. They are notable for being larger than the other spiracles to a greater degree than usual and being borne on small projecting lobes. The prothorax is transverse and very broad. The pronotal groove is Y-shaped, and like the uniramous prosternal groove, grades apically into a more diffuse diamond-shaped depression with a suffused orange-brown mark apically.

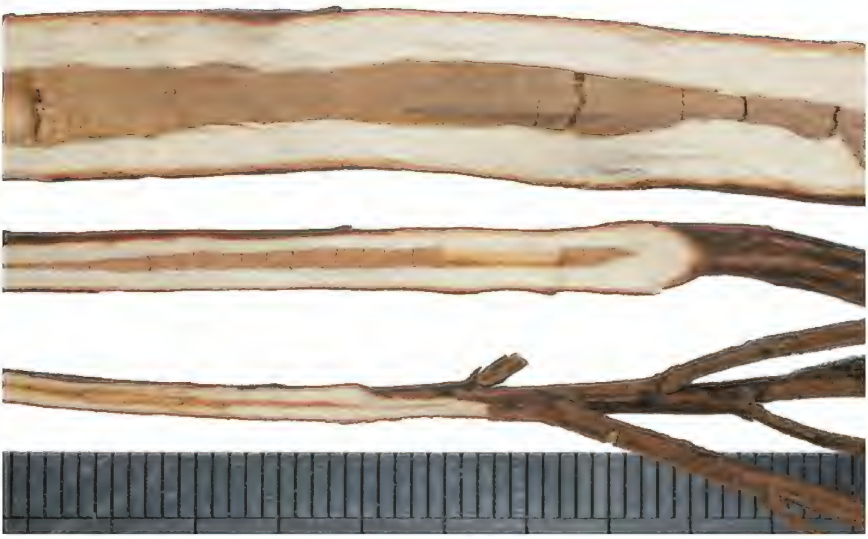


Fig. 17. *Choretrum glomeratum* (PJL 3273), site 3: split sections of branch and branchlets showing central core of fine frass that was continuous with pupal chamber of prepupa PL4015 (scale graduations: 1 mm).

Breeding behaviour

Our observations show that *Microcastalia globithorax* breeds in live stems of two *Choretrum* species, with larvae progressing from small sub-terminal branchlets and feeding down through the centre of stems to pupate near the base of the trunk or major branches in a chamber that may reach to within a few millimetres of the stem surface. Adults chew through the outer stem to emerge in mid-summer.

Only two specimens, found at Sites 2 and 4, were associated with dead wood. Both were non-emerged adults in a dead branch on a live bush, and may have fed as larvae on live wood before the branch died. At Site 2 the branch was alive when visited 11 months earlier.

The large size of final instar larvae and concurrence of life stages at Sites 2, 3 and 5 (Table 1), indicates a life cycle of at least two and probably three years duration.

Microcastalia scintillans

This species is well differentiated from *M. globithorax* by the many diagnostic characters included in the key of Bellamy and Peterson (2000). It can also be separated by a reduction in the thickened shiny flat areas around larger fossae of the pronotum that are so pronounced in *M. globithorax*.

Nine SA specimens of *M. scintillans* from near Sinclair Gap on north-eastern Eyre Peninsula (Fig. 1) were identified in the SAMA collection. These, and a single *M. globithorax*, were collected by P. Hudson from 1998 to 2006 as dead

remains in the strand deposit of a salt lake. The Australian Virtual Herbarium (AVH, 2020) has no records of *Choretrum* in that area and searches by PJL located none. Several *Santalum murrayanum* (T. Mitch.) C.A. Gardner, a small tree also in Santalaceae, were present but had no signs of borer activity.

One *M. scintillans* specimen was identified from a private collection (Fig. 23). It was collected live on an *Acacia* branch 106 km NNE of the previous locality (M. Hura, 31 km NW Port Augusta, 25 Dec 2008).

Discussion

The 32 vouchered specimens of M. *globithorax* from the nine sites (Table 1) comprise 16 adults, 2 pupae, and 14 associated larvae (3 prepupal). Together they provide strong evidence for the regular use of *Choretrum* by *M. globithorax* as a larval host (8 sites, 22 specimens), and adult host (2 sites, 10 specimens). The greater number of records for larval host usage compared to that for adults is a reversal of the usual situation in Buprestidae.

These are the first reported breeding records for *Microcastalia,* and specifically for *M. globithorax* shown here to breed in *Choretrum chrysanthum* (at two locations 17 km apart on Eyre Peninsula) and in *C. glomeratum* (at four locations spanning 54 km in the upper south-east of SA and two sites 8 km apart on Eyre Peninsula). Breeding in *Leptomeria aphylla* is also established based on a single specimen at one site in the upper south-east of SA.

Our observation of apparent ovipositing or pre-ovipositing behaviour in *M. globithorax* agrees with Peterson's (1996) report of a *Temognatha chalcodera* (Thomson, 1878) landing on top of a shrub, walking down to the base, turning 180 degrees and returning up the trunk to oviposit at 70 mm above the ground. In our observations no eggs were detected where the female paused, but it was partly obscured while amongst the foliage. From our later observations of the internal frass strand, oviposition would be expected on the upper branchlets.

The *M. scintillans* records extends the species known range into western SA. The occurrence of a single adult on an *Acacia* branch may be incidental. The absence of *Choretrum* in the lake strand deposit area is inconclusive, as the specimens may have been blown from further afield by extreme weather, as apparently have other unusual finds in that deposit. Larval host plants used by *M. scintillans* remain unknown and their discovery would be of great interest.

The significance of the *M. globithorax* host discoveries is underlined by the absence of previous *Microcastalia* records in a dataset compiled by PJL of over 7,200 SA buprestid specimens that have host data, for over 240 different host plants (Lang 2020). After the first observation on *Choretrum*, targeted searching produced many new *M. globithorax* records, much exceeding the five specimens that had accumulated in SAMA over the previous 140 years.

The rarity of *M. globithorax* in collections seems to reflect genuine rarity in the field. Its occurrence at Barwell CP was very localised compared to the available host plants. Also, the three host species are generally uncommon and

Figs 18, 19. *Microcastalia globithorax* from *Choretrum glomeratum*: (18) pupa (PL4113) 15.8 mm long, from site 6; (19) non-emerged male adult (PL4104) 11.7 mm long, extracted from stem base at site 5 and photographed on flowering branchlets of larval host.

patchily distributed which would limit abundance of the buprestid. Another reason for apparent rarity of *Microcastalia* may be because usual methods of foliage and flower searching do not detect it. Adults were found on *Choretrum* bushes at only two sites, with no sign of foliage feeding. Nor did live adults in containers feed on provided foliage. *Microcastalia* adults lack projecting or brush-like mouthparts related to flower feeding, and have not been taken in normal buprestid-associated flowers such as *Eucalyptus*, *Melaleuca* and other Myrtaceae. The present records of male and female adults on two *Choretrum* spp. may be because of recent emergence or mating/oviposition behaviour rather than plant feeding. *Microcastalia globithorax* emerges later than most buprestids and may have a short, non-feeding adult life span. This may also apply in the related *Neobubastes* for which no clear adult host plant associations are known.

Choretrum glomeratum and *C. chrysanthum* are very closely related, and at one stage (Jessop 1986) they were separated at variety rank only, with var. *chrysanthum* treated as a yellow-flowered variety of typical white-flowered *C. glomeratum*. Separate species rank is supported by differences in stem and floral morphology (Lepschi and Barlow 2012) and preferred soil types that correlate with flower colour. Both species also occur in WA and the attraction there to yellow buckets accords with the yellowish foliage of *C. chrysanthum* (Figs 2–4), and to lesser extent, of *C. glomeratum* (Fig. 19), whereas blue or red buckets would be expected for an attraction based on body colours that is also often observed in buprestids. It implies that the need to locate a host plant overrides or precedes that of finding a mate.

Other *Choretrum* species occur within the range of *Microcastalia* and further investigation is needed to ascertain whether they too are utilised, and whether the single instance of *Leptomeria* as larval host is merely incidental.

Figs 20–22. *Microcastalia globithorax* late instar larvae. (20, 21) Head and thoracic segments in dorsal (left) and ventral view, showing pronotal and prosternal grooves and large spiracles of mesothorax: (20) larva from *Leptomeria aphylla* stem base (PL4188), 5 mm wide; (21) larva from *Choretrum glomeratum* stem base (PL4127A), 4.8 mm wide). (22) Entire larva in ventral (above) and dorsal view (PL4127A) 25 mm long.

Fig. 23. *Microcastalia scintillans* (MAH 04165) from 31 km NW Port Augusta, 14 mm long, in dorsal and ventral view, and closer view of dorsal anterior (photographed by Mark Hura).

This is the first record of *Leptomeria* being used as a host plant for Buprestidae. Notably, *M. globithorax* has not been found in or on other genera of Santalaceae such as *Exocarpos* and *Santalum* which include commoner species that have been searched by PJL for associated buprestids over many years. *Choretrum* and *Leptomeria* are allied genera set apart from *Exocarpos* and *Santalum* by their inferior rather than superior ovary. Being closely related to *Choretrum*, *Leptomeria* might provide a similarly viable alternative host across its distribution, or it may only be a secondary host dependent on 'spillage' from infestations in nearby *Choretrum*; further records are needed to demonstrate a definite host relationship and test these hypotheses.

Specific larval host associations with *Choretrum* have also been discovered for two other unrelated buprestid species in SA which will be the subject of a future paper. Significantly, there is also an example in the Lepidoptera of a species that uses both *Choretrum* and *Leptomeria* as a larval host. The Australian endemic butterfly genus *Ogyris* Angas, 1847 (Lycaenidae) has one species, *O. otanes* (C. and R. Felder, 1865), that is only known to feed on *Choretrum glomeratum, C. spicatum* and *Leptomeria preissiana* (Miq.) A.DC. (Grund 2011, Grund 2020), a divergence from the Loranthaceae (mistletoe) hosts of most of its other species.

A high degree specificity in the use of *Choretrum* as a larval host by *M. globithorax* is shown by the multiple host records together with the absence of records for other host species, and is reinforced by the relative rarity of both taxa. While Santalaceae is an almost cosmopolitan family, the genera *Choretrum* and *Leptomeria* are endemic to southern Australia (Lepschi and Barlow 2012) and have transcontinental distributions (including Kangaroo Island) with centres of species diversity in south-western Western Australia. Apart from *Leptomeria* being in Tasmania, their distributions match the extent of *Microcastalia*, which also has higher diversity in the west by virtue of *M. scintillans* being known only as far east as Eyre Peninsula.

The host specificity, endemicity and comparable ranges of *Microcastalia* and *Choretrum* is consistent with them having evolved together in Australia. The discoveries reported in this paper add support to the view of Bellamy and Peterson (2000) that *Microcastalia* is 'a truly indigenous taxon' and most likely part of a more ancient Australian lineage.

Acknowledgments

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FIRST AUSTRALIAN RECORDS OF *EUPLOEA PHAENARETA CALLITHOE* BOISDUVAL (LEPIDOPTERA: NYMPHALIDAE: DANAIINAE), *XYLEUTES STRIX* (LINNAEUS) (LEPIDOPTERA: COSSIDAE: ZEUZERINAE), AND *ALCIDES AGATHRYSUS* (KIRSCH) (LEPIDOPTERA: URANIIDAE: URANIINAE)

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Abstract

Euploea phaenareta callithoe Boisduval, 1832, *Xyleutes strix* (Linnaeus, 1758) and *Alcides agathrysus* (Kirsch, 1877) are recorded from Dauan Island, Torres Strait, Queensland, and represent the first records from Australia. Their current distributions and biologies are discussed, and the historic treatment of the taxonomy of *E. phaenareta* (Schaller, 1785) is discussed. The third specimen of *Euploea wallacei melia* Fruhstorfer, 1904 is recorded from Dauan Island.

Key words: Duaun Island, Torres Strait, Queensland, foodplants, vagrancy

Introduction

Euploea phaenareta callithoe Boisduval, 1832 is currently known from mainland New Guinea and the islands adjacent to Papua New Guinea (Yata and Morishita 1985; Parsons 1999). *Alcides agathrysus* (Kirsch, 1877) is presently known only from New Guinea, while *Xyleutes strix* (Linnaeus, 1758) is a wide-ranging species occurring throughout the Indo-Australian region. During a visit to Dauan Island, in the north of Torres Strait, Queensland in February 2020, a male specimen of *E. p. callithoe* was collected, along with a specimen of *A. agathrysus* and two specimens of *X. strix*. These constitute the first Australian records of these taxa. Observations of their behaviour are presented along with notes on their distributions. In addition, the historic treatment by D'Abrera (1971, 1990) and Carver (1979) on the status of *E. phaenareta* (Schaller, 1875), including larval differences between western and eastern populations of *E. phaenareta* is discussed. As a further note, the third known Australian specimen of *E. wallacei melia* Fruhstorfer, 1904 was also collected at this time on Dauan Island.

The following abbreviations are used in the text: DAL coll., Collection of David Lane, Atherton, Queensland; MH coll., Collection of Mark Hopkinson, Cairns, Queensland; PNG, Papua New Guinea.

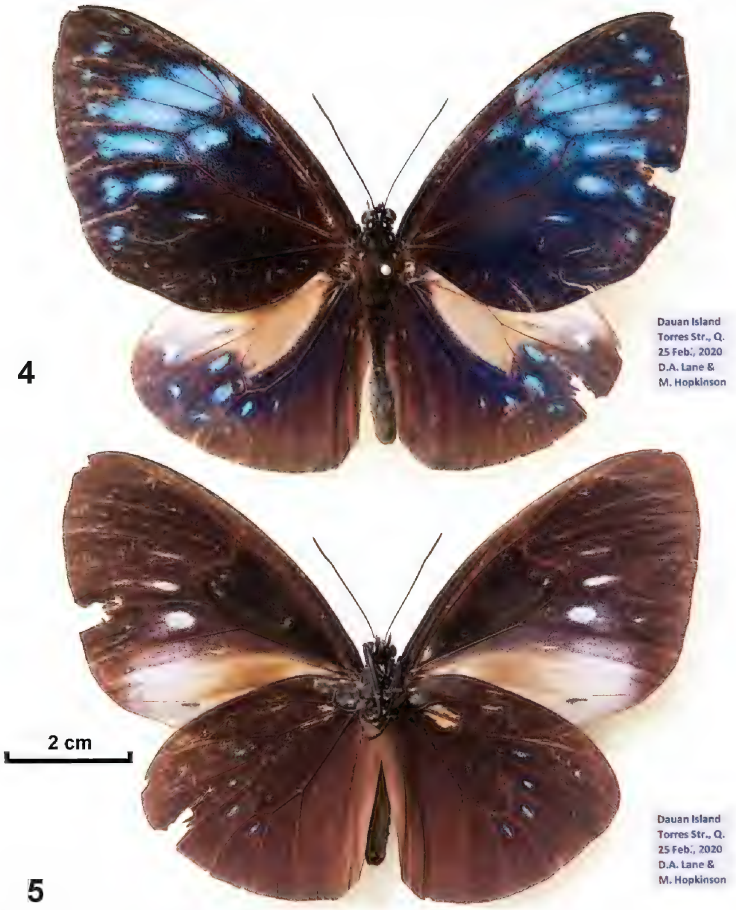
Records and discussion

Euploea wallacei melia Fruhstorfer, 1904

(Figs 1, 2)

On 22 February 2020 a male *E. w. melia* was collected as it flew through a vine thicket near the school. This specimen represents the third Australian specimen of this species following the first reported collection of a male and female from Dauan Island in 2010 (Lambkin 2016). The identification of the specimen was

Figs 1–3. *Euploea* spp. (1, 2) *E. wallacei melia*, male, Dauan Island, Torres Strait. (1) upperside; (2) underside (MH coll.).; (3) *Euploea phaenareta callithoe*, male, near Bulolo, Papua New Guinea (MH coll.).



Figs 4, 5. *Euploea phaenareta callithoe*, male, Dauan Island, Torres Strait, (4) upperside; (5) underside (DAL coll.).

confirmed by the presence of elongate white stripes in the spaces above 1A+2A and CuA_2 of the forewing underside, plus the presence of centrally placed blue spots on the hindwing underside, as detailed by Lambkin (2016).

Euploea phaenareta callithoe Boisduval, 1832

(Figs 3–5)

The male specimen (Figs 4, 5) was collected on 25 February 2020 whilst roosting under the shady canopy of a large fig tree (*Ficus* sp.) (Moraceae) near the island jetty. No further specimens were observed during the time on the island.

Euploea phaenareta has a wide distribution, extending from Sri Lanka, Myanmar, through the Malay Peninsula, Sumatra, Java and the Lesser Sunda Islands to

Flores, northward to Borneo, the Philippines and Taiwan, eastward through Sulawesi, the Moluccas and New Guinea to the Bismarck Archipelago, Admiralty Islands and Solomon Islands (Ackery and Vane-Wright 1984; Yata and Morishita 1985; Parsons 1999).

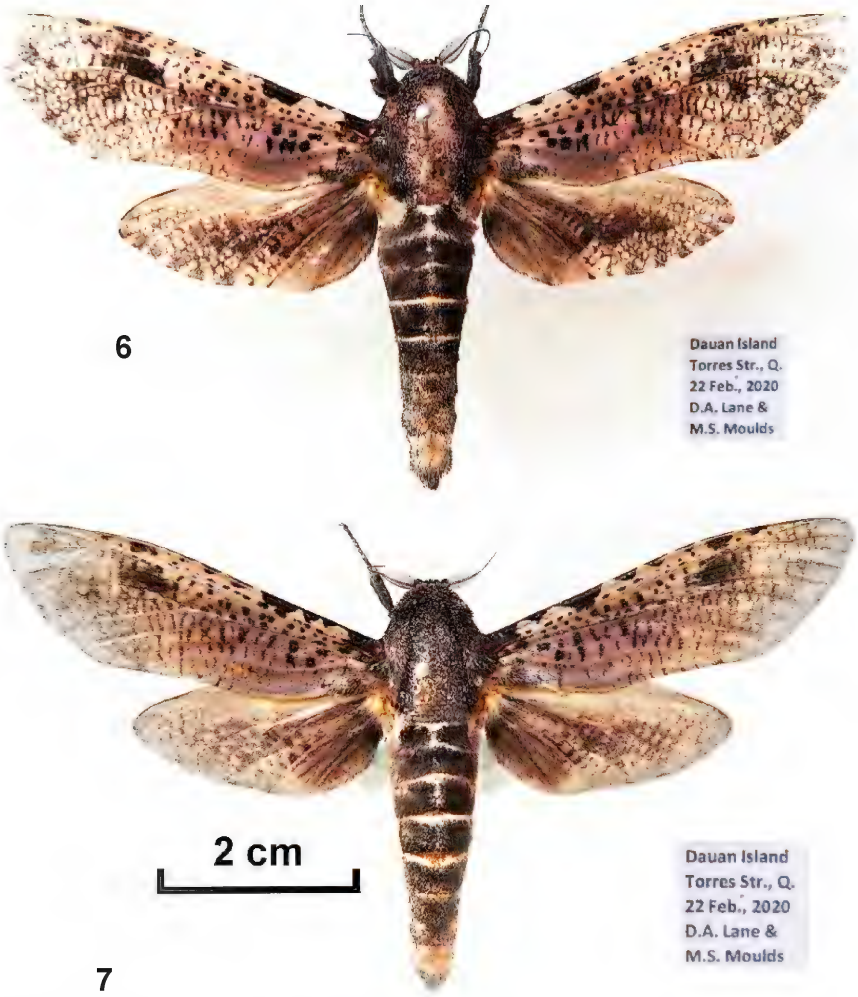
Parsons (1999) listed four subspecies of *E. phaenareta* from PNG, *viz*. *E. p. callithoe* from the PNG mainland (including western and central mainland PNG, the islands of Kairuru and Mushu, the Louisiades, D'Entrecasteaux Group, Kiriwina and Woodlark Island) (Yata and Morishita 1985, Parsons 1999); *E. p. admiralia* Strand, 1914 from the Admiralty Islands; *E. p. unibrunnea* Salvin and Godman, 1877 from Duke of York Island, New Britain and New Ireland, and *E. p. heurippa* Godman and Salvin, 1888 from Bougainville and the Solomon Islands. Both *E. p. callithoe* and *E. p. admiralia* males, though variable in facies, have large blue patches on the upper forewings, and considering the large size of this species, the species is easily recognizable. Males of *E. p. unibrunnea* and *E. p. heurippa* tend to lack the blue forewing patches, but often have extensive areas of white and brown. Overall, males of the species are extremely variable, with numerous forms having been described (Parsons 1999). Females of each of these four subspecies are equally variable.

The specimen from Dauan Island bears close similarity to two male specimens of *E. p. callithoe* from near Lae and Bulolo, PNG (see Fig. 3).

The distribution of *E. phaenareta* in southern mainland New Guinea is poorly known, with most specimens known from the northern side of the central cordillera. Butterfly movements between New Guinea and northern Torres Strait islands and the likelihood of species establishing themselves as resident populations or occurring as just vagrants in northern Torres Strait islands were discussed by Lambkin (2019). Thus, it is likely that the specimen collected is a vagrant from PNG. The recorded foodplant is *Cerbera floribunda* K. Schum (Apocynaceae) (see Carver (1979)). *Cerbera manghas* L. is a common plant on Dauan Island (Anon. (2013)) and may provide opportunity for *E. p. callithoe* to locally breed on Dauan and perhaps other northern Torres Strait islands where this plant occurs.

D'Abrera (1971) maintained that *E. phaenareta* and *E. callithoe* were distinct species and recognised five subspecies of *E. callithoe*: (1) *E. callithoe callithoe* from New Guinea, the Louisiades, Goodenough, Fergusson, Woodlark and Kiriwina Islands, inclusive of three forms, one of which (f. *hansemanni* Honrath, 1888) has large blue patches on the upperside male forewing; (2) *E. c. admiralia* from the Admiralty Islands; (3) *E. c. sacerdotalis* Fruhstorfer, 1910 from Jobi; (4) *E. c. mesocala* Vollenhoven, 1872 from Waigeu; and (5) *E. c. euthoe* C. and R. Felder, 1865 from Aru.

Carver (1979) described the early stages of *E. phaenareta* from four separate areas of Papua New Guinea, *viz*. Brown River, eastern mainland PNG, Sepik area, and New Britain. He concluded that larval forms from all four areas (which he collected separately over several years) were identical and that *E. callithoe* and



Figs 6, 7. *Xyleutes strix*. Two males collected on Dauan Island, Torres Strait (DAL coll.).

E. phaenareta were conspecific. The foodplant Carver recorded for all populations was *Cerbera floribunda*. He noted that the two filaments on segment eleven of the larvae were considerably shorter when compared with illustrations of larvae of *E. phaenareta* from Sri Lanka and the Philippines, and that this comparison might be worthy of further investigation to determine the status of populations from the western and eastern areas of their distributions.

D'Abrera (1990) reinstated *E. phaenareta* as the correct species name, based on Carver (1979), with *callithoe* as a subspecies, following the earlier work of

Ackery and Vane-Wright (1984). However, D'Abrera did not, at the time, amend the remaining four subspecies, which he inadvertently retained under *E. callithoe* (viz *admiralia, sacerdotalis, mesocala* and *euthoe*). Parsons (1999) placed *E. callithoe* and one of D'Abrera's subspecies (*admiralia*) under *E. phaenareta*. Thus, *E. p. callithoe* remains the correct subspecies name for *E. phaenareta* from mainland PNG, and is here used as the subspecies name for the specimen from Torres Strait.

Xyleutes strix (Linnaeus, 1758)

(Figs 6, 7)

Two males of this species were collected at light on Dauan Island on 22 February 2020.

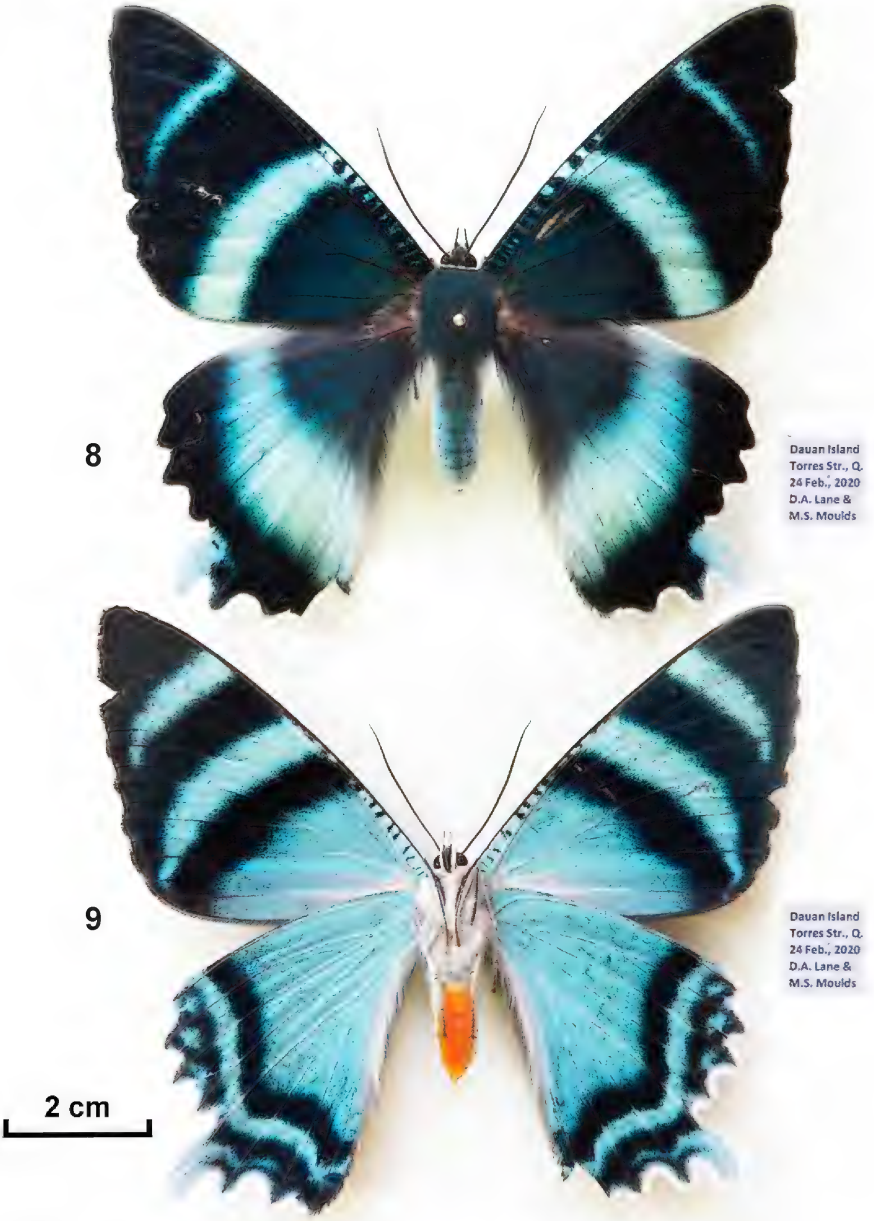
Both specimens were fresh and in good condition. *Xyleutes strix* has a wide distribution and is currently known from India, the Indo-Australian region, the Moluccas, through New Guinea to the Solomon Islands (de Vos 2020). The genus *Xyleutes* Hübner, 1820 currently contains three species within the Indo-Australian region (Schoorl 1990), with *Xyleutes persona* (Le Guillou, 1841) also widely distributed from India, Indo-Australia, the Moluccas, New Guinea and north eastern Queensland (DAL coll.; Nielsen *et al*. 1996; de Vos 2020), and *Xyleutes keyensis* Strand, 1919 known from West Papua, the Kai (or Key) Islands, and Tanimbar Island, all Indonesia (de Vos 2020).

The two *X. strix* males from Dauan Island are similar in markings to specimens from PNG and Timor Leste (DAL coll.), as well as illustrated specimens in the website of de Vos (2020). As with species of Australian cossids belonging to *Endoxyla* Herrich-Schaffer, 1854 the larvae of *Xyleutes* species in Queensland are anticipated to be wood borers within live trees, and as the three *Xyleutes* species are found in rainforest habitats, the larval food trees are expected to be rainforest species. Robinson *et al*. (2001) list *Sesbania grandiflora* (L.) Poiret (Leguminosae) as the only known host tree for *X. strix*, with the larvae feeding within stems. No larval hosts are known for *X. keyensis* but Robinson *et al*. list a range of host plant trees and shrubs for *X. persona* belonging to five families: Bombacaceae (*Durio* sp).; Leguminosae (*Cassia* sp., *Senna* sp., *Erythrina* sp.); Lythraceae (*Lagerstromia* sp.); Theaceae (*Camellia* sp.); Verbenaceae (*Congea* sp., *Premna* sp., *Tectona* sp.).

Alcides agathrysus (Kirsch, 1877)

(Figs 8, 9)

A female *A. agathrysus* was collected on Dauan Island as it fed from flowers of the Yellow Mangrove *Ceriops tagal* C.B. Rob (Rhizophoraceae). *Alcides agathrysus* is one of two Papua New Guinean species of *Alcides* Hübner, 1822, the second being *A. aurora* Salvin and Godman, 1877. A third species *Alcides metaurus* (Hopffer, 1856) is found in north-eastern Queensland, with two records from eastern Arnhem Land in the Northern Territory (Braby *et al*. 2018). *Alcides agathrysus* differs from *A. metaurus* in having bright blue forewing upperside



Figs 8, 9. *Alcides agathrysus*, female, Dauan Island, Torres Strait, (8) upperside; (9) underside (DAL coll.).

medial and terminal bands and a hindwing medial band, compared to the yellow and purple bands of *A. metaurus*. *A. aurora* has a different wing shape to those species in combination with the outer two thirds of the upper hindwing coloured pale blue, yellow and pink with the outer hindwing edged white. *Alcides agathrysus* is the model for the mimetic relationship with *Papilio laglaizei* Depuiset, 1877 in mainland New Guinea (Parsons 1999).

The life history of *A. agathrysus* is unrecorded. In north-eastern Queensland *A. metaurus* breeds on *Omphalea* sp. and *Endospermum* sp. which are vines and/or trees (both Euphorbiaceae) in rainforest areas (Common 1990). These plants are not recorded from Dauan, however a range of other plant species belonging to the Euphorbiaceae are known from Dauan (Anon. 2013).

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This common eastern Australian mantid, *Sphodropoda tristis*, was described in 1871 by Henri Louis Frédéric de Saussure, an early Swiss worker on orthopteroids and wasps. Its Latin species name means 'sad'. Adults reach 63 mm and are greyish brown with fine patterning. When ready to deposit her ootheca, the female excavates a hole in soft soil with her strong, toothed forelegs. She backs into the hole, deposits the ootheca, then refills it using mid and hind legs. This was first observed by Brisbane school teacher, Roly Chapman, in 1981 and was published in this journal in 1984 (Vol **11:** 5–7). Illustration is pen/ink stippling on paper by 2020 ESQ President, Mark Schutze, who is in charge of the DAF insect collection at Ecosciences Precinct in Brisbane. More of his work can be seen at exoskeletonprints.com/prints.html

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